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Juice Processing.
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FOREWORD

By The Right Honourable Viscount Bledisloe, P.C., G.C.M.G., K.B.E.

Compliance with the request that I contribute a Foreword to this revised edition of an epoch-making Bulletin entitled *Fruit Juices and Related Products* which was published ten years ago, affords me particular pleasure, first, because I am a convinced Imperialist, keen to see the British Commonwealth leading the world in all projects for the salutary application of science to human well-being, secondly, because I deem the skilled production and largely-increased consumption of fruit juices and allied products to be fraught with results highly conducive to health and efficiency, thirdly, because I have a profound admiration for the genius and ability of Dr. Vernon Charley, its Editor, and fourthly, because as Chairman, in 1927, of the Imperial Agricultural Research Conference, which brought into existence the various Bureaux of Agricultural Research, I am naturally interested in any publication sponsored by one of the most active of them.

In the First World War, during part of which I represented in the House of Commons the newly-formed Ministry of Food, the measure or yardstick of human nutrition was calories, or energy units (reckoned in terms of fats and carbohydrates), balanced by proteins. In the Second World War, while it was recognized that these supplied the basic conditions of subsistence, emphasis was transferred to those accessory food factors known as vitamins, especially vitamin A, affording protection against disease, and vitamin C, as being anti-scorbutic and physically stimulating. Moreover, within three years from the outbreak of war, the Ministries of Food and Health gave official encouragement to the processing of blackcurrants and rose hips, on the ground of their high vitamin C content, stressing particularly the use of preparations of the former in the feeding of infants.

The abnormally high standard of the health of the nation during this second period of world upheaval, anxiety and distress, during which Britain was one of the war fronts, is traceable (apart from the rigorously applied policy of food equalization) in no small measure to this timely emphasis on vitamins, and notably vitamin C, of which fruit juices and their related products are the best known and most effective vehicles to the human organism.

The truly remarkable advance made during the war period, and since, both in the consumption of these products and in the mode of their production and preservation, fully justifies the issue of this second Bulletin, ten years after that of the first.

One small, but significant, difference in stress is to be found by careful comparison of the two publications. In the former it was the importance *to the fruit industry*, as conducted within the British Empire, of the profitable utilization of its largely wasted output and the growing appreciation of its derivatives in the form of refreshing beverages which were nutritious and stimulating (albeit unfermented) which appeared to supply its main *raison d'être*. In this publication, quite properly, the stress passes to the enormously important bearing of these products upon human physique, health and efficiency. Moreover, under commodity-shortage conditions during the war and post-war periods, necessity has proved itself the mother of invention in many salutary directions. Thus to minimize bulk and so reduce transport costs the natural fruit juices were submitted to high concentration, and similarly the shortage of steel led to the use of refrigeration to enable thinner and lighter metal to be used for fruit juice storage tanks. Improved flavour appears to have proved one further incidental advantage of this change.

Contributions of new scientific knowledge and new economic methods of processing continue to arrive from different parts of the British Commonwealth, not the least interesting being the determination by the Cawthron (Research) Institute in New Zealand of the relative vitamin C content of the various dessert apples grown in that Dominion for export to Britain, demonstrating the marked superiority in this respect of " Sturmer Pippin " (even after long storage) over all other varieties.

This Bulletin merits careful perusal, especially by those in every part of the Empire who can produce the right type of fruit to yield this new-found *Elixir Vitae* and those who, by skilful processing, can, with profit to themselves, render it marketable in fresh and palatable condition.

While improved productive technique is its main theme, the all-important recognition, both by medical experts and Governments, of the health-giving properties of these fruit products cannot fail to secure for them a steadily increasing popularity.

It may well be that, as the world population is increasing at a faster rate than current world output of essential foods, the presently barren areas of tropical and sub-tropical countries may come to supply not only the bulk of the vegetable fats requisite for the optimum *per capita* ingestion of calories needed for sustenance and human activity, but also the raw materials which provide those vitamins deemed indispensable for perfect health and the *joie de vivre* which accompanies it.

The British Commonwealth is particularly well equipped to pave the way for such events.

R.M.S. *Pretoria Castle*,
en route for South Africa,
January 17th, 1949.

BLEDISLOE.

CHAPTER I

INTRODUCTORY CONSIDERATIONS

Nine years have passed since the publication of *Fruit Juices and Related Products*, the first Bulletin to deal with this subject in the series sponsored by the Imperial Bureau of Horticulture and Plantation Crops—as its title was in 1939. This period coincided with the most widespread and devastating war ever suffered by mankind, followed by four years of the inevitable aftermath of such a clash among the nations of the world. To an onlooker from another planet, such a period of mad destruction, of a struggle for supremacy by force of arms would seem to be a most unlikely time in which to expect significant developments in such peaceful pursuits as agriculture and allied industries. How strange, then, to find that the processing of fruit juices has advanced since 1939 at an amazing rate, simultaneously with an all-embracing war effort, and to a large extent as an inherent and important phase of the combatants' efforts to secure victory.

Fruit Juices and Related Products presented the scattered data available at that time relevant to the nutritional value of fruit products. Of what did this evidence consist ? Cases of ulceration were alleviated by blackcurrant syrup, young children suffering from pink disease obtained relief from apple juice, and a whole range of complaints were being treated in Germany and Switzerland by the administration of pure, unfermented fruit juices in hospitals provided with specialists skilled in fruit juice cures.

Impressive as these scattered references might have seemed in 1939, they were merely isolated cases from many countries, and the great preponderance of the fruit juices then in commercial production were consumed merely as refreshing beverages without thought of their conveying to the consumers any fundamental nutritional constituents. But war can play strange tricks and wider issues than the mere production of armaments and their economical and effective use against the enemy soon engaged the attention of the combatants.

Prominent amongst such considerations was the question of feeding the population so effectively that its morale and productive capacity were maintained at a high level to satisfy war-time requirements. In the British Isles, the Ministry of Food introduced the basic conception of claims of priority consumers (children, expectant mothers and invalids) and throughout the war and until the time of writing this Bulletin, special provision has been made for the supply of certain fundamental nutrients for these classes of the population. The drastic reduction in the importation of fresh fruit was the primary cause for Government action and the well-known scheme for the distribution of blackcurrant, orange and rose hip syrups, all with high vitamin C contents, came into being at a most difficult stage of the war so far as this country was concerned. The importance placed on such schemes by the Government can surely be most effectively assessed by the high priority given to the production of such syrups when the productive capacity of the nation was being stretched to its utmost limits by the munitions programme. Scientific research was planned and technical processes developed by scientists reserved for this purpose. Plant of special construction in stainless steel had to be provided ; processes were overhauled to ensure maximum retention of nutritive value in the products ; schemes for the diversion of fruit supplies into the necessary factories had to be arranged at very short notice and comprehensive chains of distribution centres were established in every locality in the British Isles.

From a position in 1939 where fruit juices were regarded as having a useful but limited importance in nutritional practice, the situation rapidly developed, so that in 1940-46 fruit products were being regularly consumed by those classes considered to be most in need of them, from Land's End to the Orkney Isles. In 1938, a small child improved rapidly in health as the result of the administration of unfermented apple juice, and in the words of the doctor in charge of the case " this use of apple juice seems to be the first time when fruit in any form has been specially employed here for the improvement of health ". Four years later, all children and other priority classes in these Islands were being regularly supplied with vitamin syrups to take the place of fruit, which by then had become so short in supply that it contributed only a negligible proportion of their daily needs of vitamin C. It is a sad reflection that a war is needed to encompass such fundamental changes and improvements in the nation's dietary, but it is likewise encouraging to find that the position has not been allowed to revert to its former unsatisfactory status and that the distribution of fruit products appears to have become a regular and stable feature of our national nutrition.

Many other cases where fruit juice developments have been directly initiated by war conditions can be cited. The arrival of American soldiers en masse in Australia was responsible for the sudden and large scale production of apple juice, fortified with ascorbic acid, for the provision of vitamin C for those troops where daily intake of this vitamin could not be maintained by the other foods provided. The insistence of nutritional experts on the importance of a regular, daily intake of vitamin C threw into relief the value of fruit juices containing ascorbic acid ; fresh fruit of the citrus type could certainly be used when in season, but difficulties of transport and lack of continuity of supplies of the fruit in fresh condition clearly favoured the use of juices or syrups which could be produced in bulk during the season and whose transport and distribution showed appreciable economies when compared with the provision of similar amounts of ascorbic acid in the form of fresh fruit. Apple juice in a fortified condition was also prepared in very large gallonages in America and Canada—a fact that may cause amazement in the minds of those who regard the inhabitants of the North American continent as being able to consume a wide variety of fruits to an almost unlimited extent. It is almost paradoxical to read that in 1946 the Combined Food Board on food consumption levels in the United States, Canada and the United Kingdom reported that vitamin C was the only accessory food factor seriously deficient in the diet of the Canadian population ! The techniques of adding ascorbic acid to apple juice and of retaining in tomato juice appreciable contents of natural vitamin C were worked out during the war to meet this particular situation and our present knowledge of fruit juice processing has been widened and more firmly based on precise scientific premises as a direct result of these studies instituted to meet a sudden war-time emergency.

This urgent necessity to retain the maximum possible amount of the ascorbic acid and other nutritional elements in the original fruit juice proved to be a veritable labour of Hercules. The instability of the vitamin in many normal conditions of fruit juice processes is well known, and a complete review of the factors influencing its retention was an indispensable preliminary to the practical solution of the plant problems. In this way, de-aeration and flash pasteurization were accepted as necessary inclusions in the scheme of processing, and chemical engineers in many countries quickly applied the theoretical and laboratory scale studies to the design of large plants each suitable for dealing with many thousands of gallons per day. Completely new conceptions of processing were thus introduced on account of the " new (nutritional) look " of fruit juices.

Such developments as these, in which the processing is dictated primarily by nutritional rather than organoleptic considerations, may, however, have repercussions beyond the scope of the original intention of the technician. For example, the process of de-aeration will have a very marked effect on the retention of ascorbic acid in a fruit juice, but equally significant effects can be seen on the freshness of flavour and colour of the juice. One has thus observed the interesting position in which processes which have been introduced solely to improve the nutritional value of the juice have effected a most marked and permanent improvement in flavour and appearance in the product.

Developments in the British Commonwealth tended to lag somewhat behind those in America, but they have been appreciable and the pace set during the war has been accelerated in the post-war years. It became necessary in 1940 to restrict the importation into the British Isles of straight, unconcentrated citrus juices, and the provision of suitable concentrates from Commonwealth sources became an urgent necessity. All over the Commonwealth fruit juice processing was re-orientated to provide those products which were most important to the war effort ; fruit juice extraction methods were radically overhauled, evaporation techniques were improved and it was the proud boast of producers of Southern Rhodesian concentrated orange juice that the product made there was richer in ascorbic acid than that from any other source. Smaller colonies were encouraged to expand their fruit juice industries and in December 1948 the British Minister of Food announced that the Ministry had made forward contracts for five years with the British West Indies to enable the industry there to stabilize its economy and make its own contribution to the fruit juice position. [The specific processing developments in the Commonwealth are dealt with separately in Chapter XII.]

The fruit juice industry can be regarded as having been born in Europe, and probably Switzerland can claim pride of place as being the first country to develop the commercial production of pure fruit juices. During the past ten years, that country has been faced with manufacturing problems which were to some extent the direct result of the war being waged around its frontiers. In the first place, the heavy, lined steel tanks of the Böhi type which were originally developed in Switzerland for the bulk storage of juices under CO_2 pressure, became impossible to fabricate on account of the acute shortage of steel and the technicians turned their attention to methods of saving steel by the use of lower pressures of CO_2 which automatically called for the use of much thinner steel. The outcome of this search for an improved process was the erection of a cold store around the tanks so that the juice could be maintained at 1° C. Here, again, where necessity had been the mother of invention, the fruit juice processors gained a double advantage. Beside the very considerable saving in steel that resulted by adopting the new technique it was found that the flavours of the juices were vastly improved by being stored at such a low temperature.

From the same country comes another example of war-time exigencies fostering improved techniques in the fruit juice industry. The shortage of tank storage suggested to certain refrigeration experts that the solution might be found by storing frozen juices in silos which could be simply and cheaply constructed. A process was eventually developed (see Chapter II) whereby a " snow " of frozen fruit juice could be stored in lined concrete silos maintained at — 25° C.

Lastly, as an illustration in another sphere of fruit juice work, may be quoted the latest Swiss technique for vacuum evaporation of juices. The war imposed on that country the severest restrictions in supplies of imported fuel and the maintenance of large evaporators operated by steam became a matter of deep concern to the industry. A fascinating method of obtaining heat from a relatively " cold " material such as river water had been evolved by the development of the heat pump, and the Municipal Buildings of Zurich had been warmed by heat abstracted from the water of the River Limmat which runs through the city. The heat pump calls for very appreciable supplies of electric power, but this is relatively cheap in Switzerland as it is mostly produced by water power. The latest Swiss evaporators (Chapter V) now make use of this principle and whilst the plant calls for more electric power than may be economical in other countries, the evaporation calls for practically no steam or cooling water, and the concentration is effected almost at normal temperatures.

The remainder of this Bulletin is devoted to a review by various writers of the major developments that have occurred during the past ten years. Technique of production is the main theme and in consequence no attempt had been made to collate information regarding production data, economic considerations or the use of fruit products for the treatment of specific ailments or diseases. It is becoming increasingly clear that the controlled administration of some fruit juices has a total effect which cannot be entirely attributed to the ascorbic acid content of the product, but the evidence is not yet sufficiently conclusive for a categorical statement to be included here, and, in any case, the present publication would be inappropriate for a medical discussion of considerable complexity.

The scope of this Bulletin has been selected by the writer, who, apart from editing the whole production, has himself contributed those chapters where acknowledgement of alternative authorship is not made. Chapters III and IX, of Canadian authorship, recently published as a separate Bulletin [see footnote to Chapter III] present the most up-to-date information regarding Canadian and American processing in detail. In Chapter IV, the principles and practice of de-aeration and pasteurization are presented in such detail as the importance of these processes now warrants. Information regarding the vitamin C content of fruits and their juices has been apt to be given within narrow limits, i.e. with reference to the fruits of one country or continent only, but in Chapter X an attempt has been made to give a more general résumé of the present position and to include information which has come to hand concerning fruits in many areas outside Europe and North America. Lastly, the use of enzymes for the clarification and stabilization of fruit juices has advanced in many fundamental aspects during the past ten years, and Chapter XI has been specially prepared to provide a comprehensive exposé of the present position regarding the theoretical background and practical manipulation of enzymes in fruit juice manufacture.

CHAPTER II

SOME GENERAL DEVELOPMENTS IN PROCESSING AND BOTTLING FRUIT JUICES*

Very few entirely new principles have been discovered and applied to fruit juice processing during the past ten years. Most of the improvements have concerned increased efficiency of plant, more suitable materials for plant and storage vessels and the building of machinery with a due regard to its sterilization. In the following review of the more important of these aspects of the fruit juice industry, it is presumed that the basic processing methods as outlined in the previous Technical Communication are well known and no reference will be made here to processes in which little advance has been achieved since 1938. The latest Canadian and American procedures are discussed separately in Chapter III.

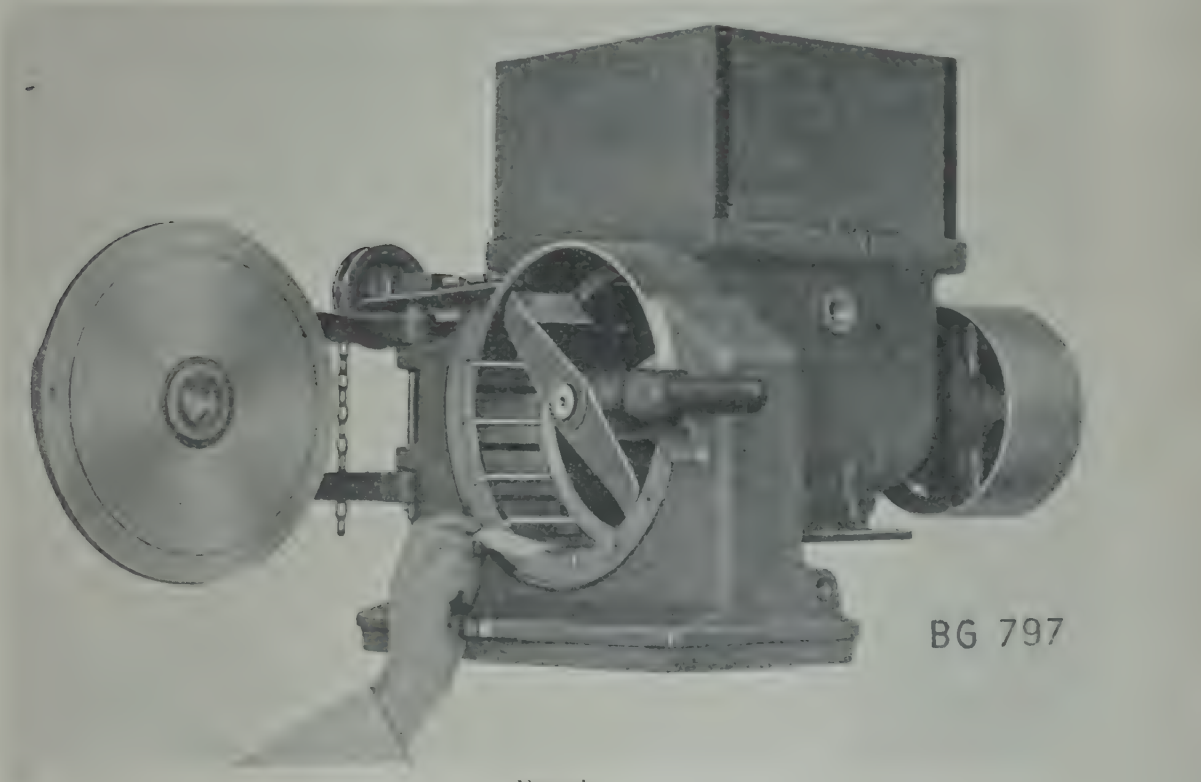

Fig. 1.
Bucher-Guyer mill.

(a) Fruit storage and washing

The washing of fruit has become an essential feature of the juice industry. As the tonnages involved have increased, the problem of dealing with thousands of tons of fruit has grown in importance and many very large installations have been developed to provide safe storage for the fruit and convenient transport from the bins or silos to the mills. In this connection, water is being increasingly used in the dual capacity of a motive force and washing agent. In many cases, the apples can be efficiently washed merely by being moved slowly forward in a semi-circular trough by a continuous screw operating in a slow stream of water which cleans the fruit and deposits the dirt in specially sited wells from which it can be removed from time to time. There is little need in European practice to use acidified water for this purpose, but in North America the apples are generally washed in a very dilute solution of hydrochloric acid to remove noxious spray residues from which the juice may acquire a content of harmful metals, such as lead or arsenic, which would be in excess of the legal maxima.

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* Mostly of European origin.

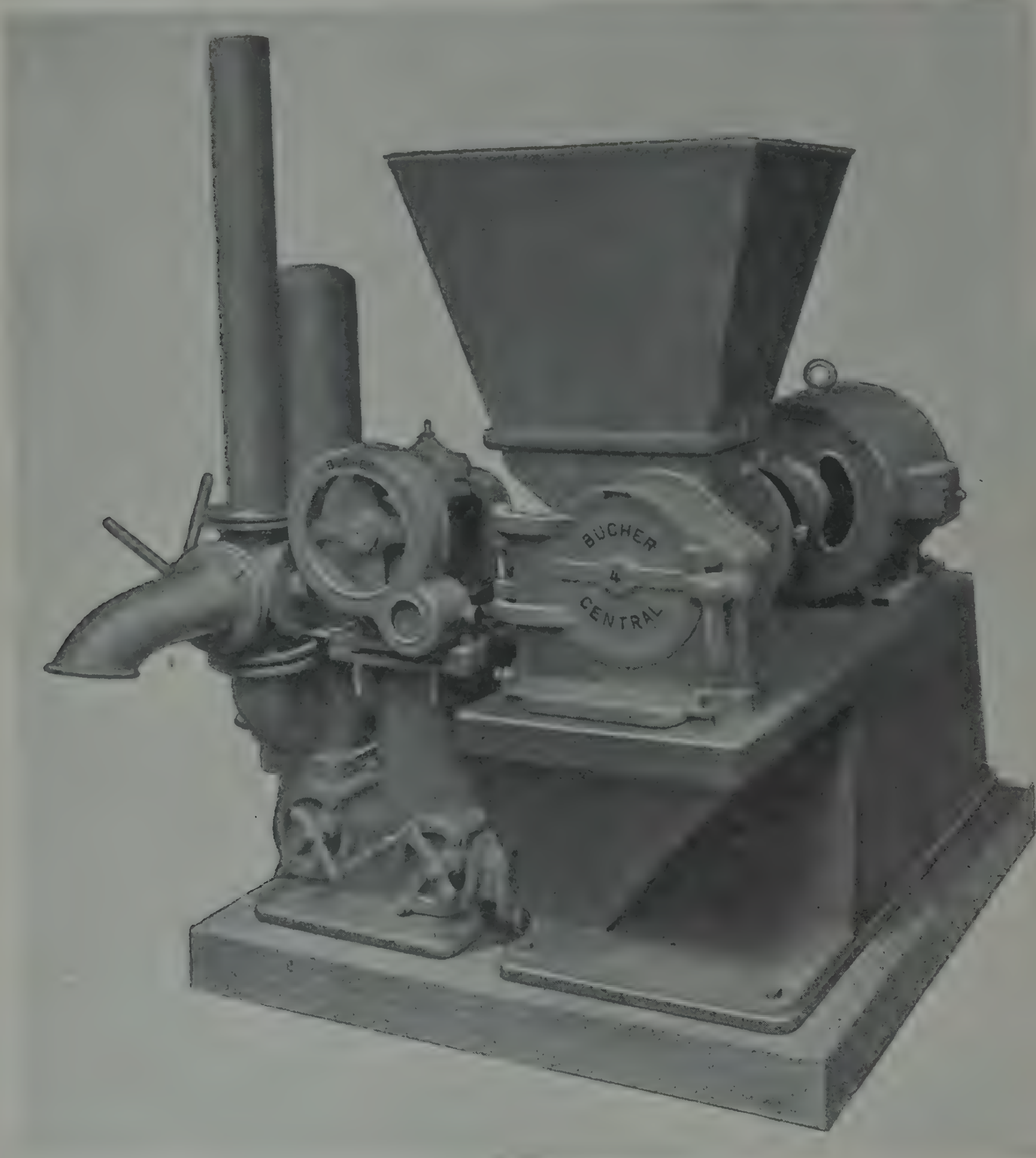

Fig. 2.

Bucher-Guyer mill with attached pump.

(b) Fruit mills

The most popular mill for disintegrating the fruit still appears to be the grater typ
This mill can be made in stainless steel with totally enclosed ends so that its cleaning becom
a relatively simple matter, as there are no places where fruit tissue can find a permane
lodgement. Such mills, however, work at high speeds and are subject to considerable we
and tear. The hammer-type mill of American introduction is still widely used in that count

but has not gained popularity elsewhere. European practice, however, has been improved in recent years by the introduction of mills such as the Bucher-Guyer type, which provide a very finely divided pulp by a two-fold system of disintegration. The fruit is first crushed into a coarse pulp by a simple mincing machine action and this pulp is then impelled through a sieve by a series of beaters operating against serrated knife edges set in a circular fashion (Fig. 1). The Bucher-Guyer mill can, moreover, be fitted with a pump (Fig. 2) capable of handling the pulp and transporting it over a considerable distance to the presses. This, again, is a feature of many modern fruit juice factories, where the older idea of tall, many-storied buildings has fallen into disfavour. It is now possible to mill the fruit on the ground floor (for convenience of dealing with the raw fruit) and to pump the pulp to such a distance and height as is necessary to suit the particular needs of any given installation.

The fineness of division of the pulp from this type of mill may on occasion cause difficulties by the very reason of its smooth consistency. Soft textured apples and soft fruits such as blackcurrants may not react so favourably to its ministrations as the apple and pear, but this trouble can often be avoided by adjusting the setting to the knives. Other types of mills of American introduction are dealt with in Chapter III (pages 47, 53, 54).

(c) Hydraulic fruit presses

It is one of the amazing inconsistencies of the fruit juice industry that despite its many modern achievements substantially the same method of pressing juice from apples should be employed to-day as was used two hundred years ago. Illustrations as far back as 1710 show a country gentleman in sober apparel pressing out a stream of juice from smashed apples using racks and cloths of rudimentary design but nevertheless showing undoubted signs of having the same basic principles as those employed to-day in 90 per cent. of the fruit juice industry which uses fruit that undergoes a pressing operation. Hydraulic presses have improved in design and power in recent years, although there has been a tendency amongst some technicians to deplore the increasing use of additional pressure beyond certain limits. These presses, when built in batteries of three or more units, are generally actuated by an accumulator which avoids the waste of time in waiting for an individually powered hydraulic pump to take up the slack space and commence the actual pressing operation. The cheeses are now usually built on a trolley which is capable of being raised and lowered on a hydraulic jack, so that the workmen are able to work at the same level from the first to the last cloth of the cheese. In this way much personal fatigue can be avoided with consequent increase in output. European practice still uses wooden racks and cloths of hemp, cotton and woollen materials.

The chief pressing development in recent years has been the introduction of the three-stage rotary presses which avoid the use of transfer trucks and thus are very economical in space and labour. These new presses have been developed in Switzerland by the firms of George Fischer and Bucher-Guyer. The former press is now being produced in England by Messrs. Tangye (Birmingham) whilst the Bucher-Guyer plant is under licence for production by Messrs. H. Beare & Sons Ltd. (Newton Abbot).

Whilst photographs of both plants are shown, a description will only be given of the Tangye equipment. The latest press is the three-tray rotary press (Fig. 3) which can deal with 32 tons of apples in an 8-hour day. Each cheese contains 18-24 cwt. of pulp, according to the size of the press, and the actual pressure exerted on the pulp is, at the maximum, 348 lb. per square inch. The power requirements are very moderate, 2½ h.p. for the press and 5-6 h.p. for the mill.

Certain features of these Swiss presses are worthy of special mention :

(i) Each cheese receives two separate pressings.

(ii) A drum-measuring device allows exactly the same quantity of milled pulp to fall on to each cloth, thereby ensuring an even cheese construction.

(iii) The drum-measuring device can be automatically adjusted to deliver the pulp at regular intervals, these being timed to suit the capabilities of the workmen concerned.

(iv) The pulp is subjected to a pressure of 130 lb. per square inch in the first pressing, and to approximately 350 lb. per square inch in the second. The first operation is effected

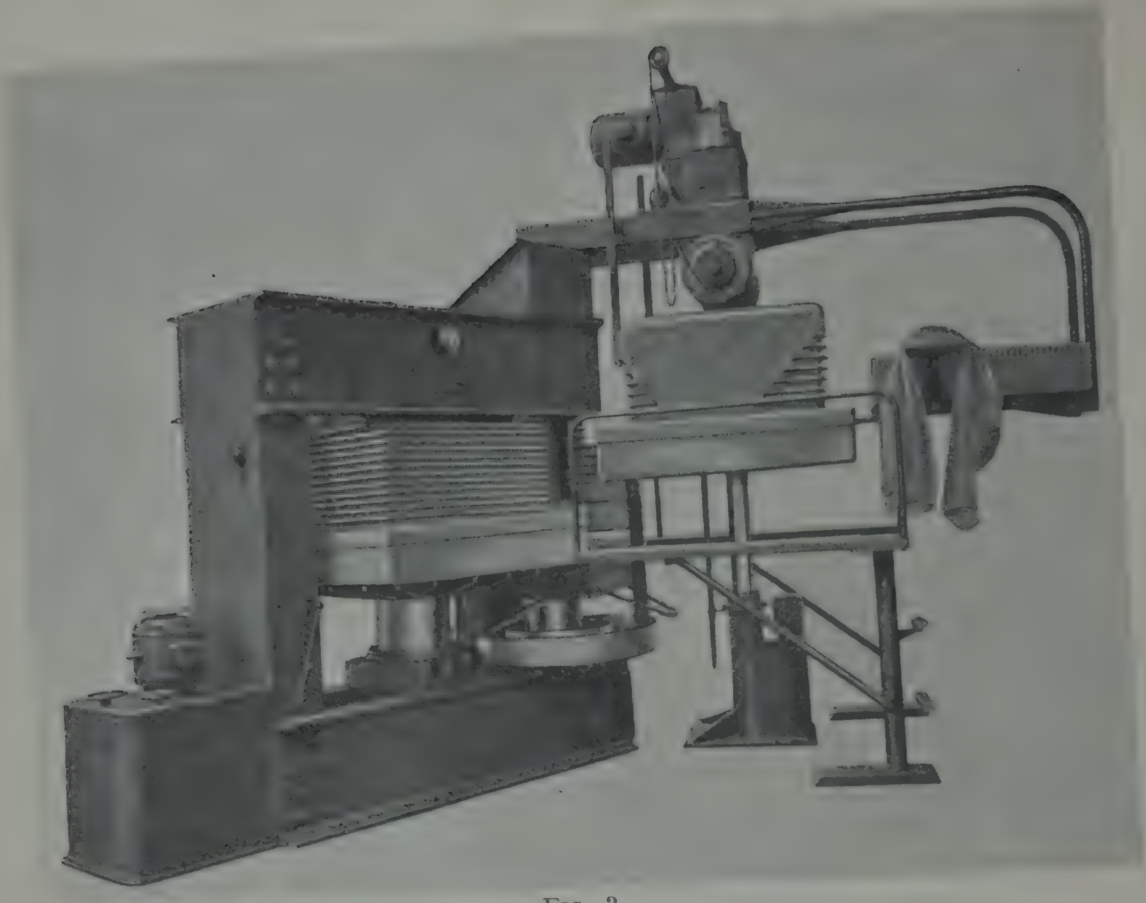

Fig. 3.
Bucher-Guyer three-tray hydraulic press.

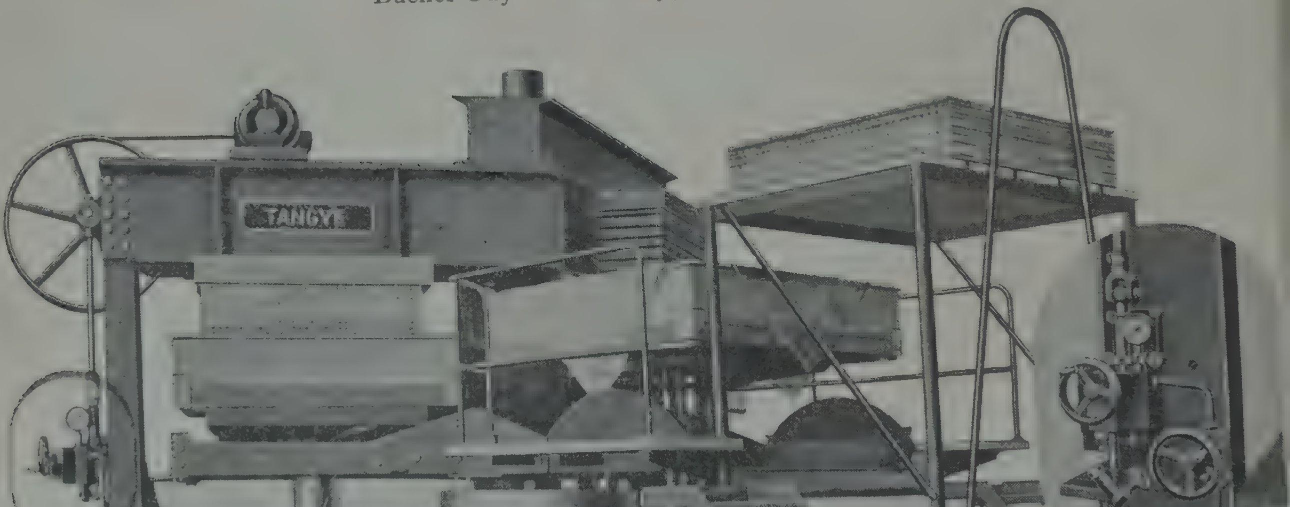

Fig. 4.
Tangye three-tray rotary press.

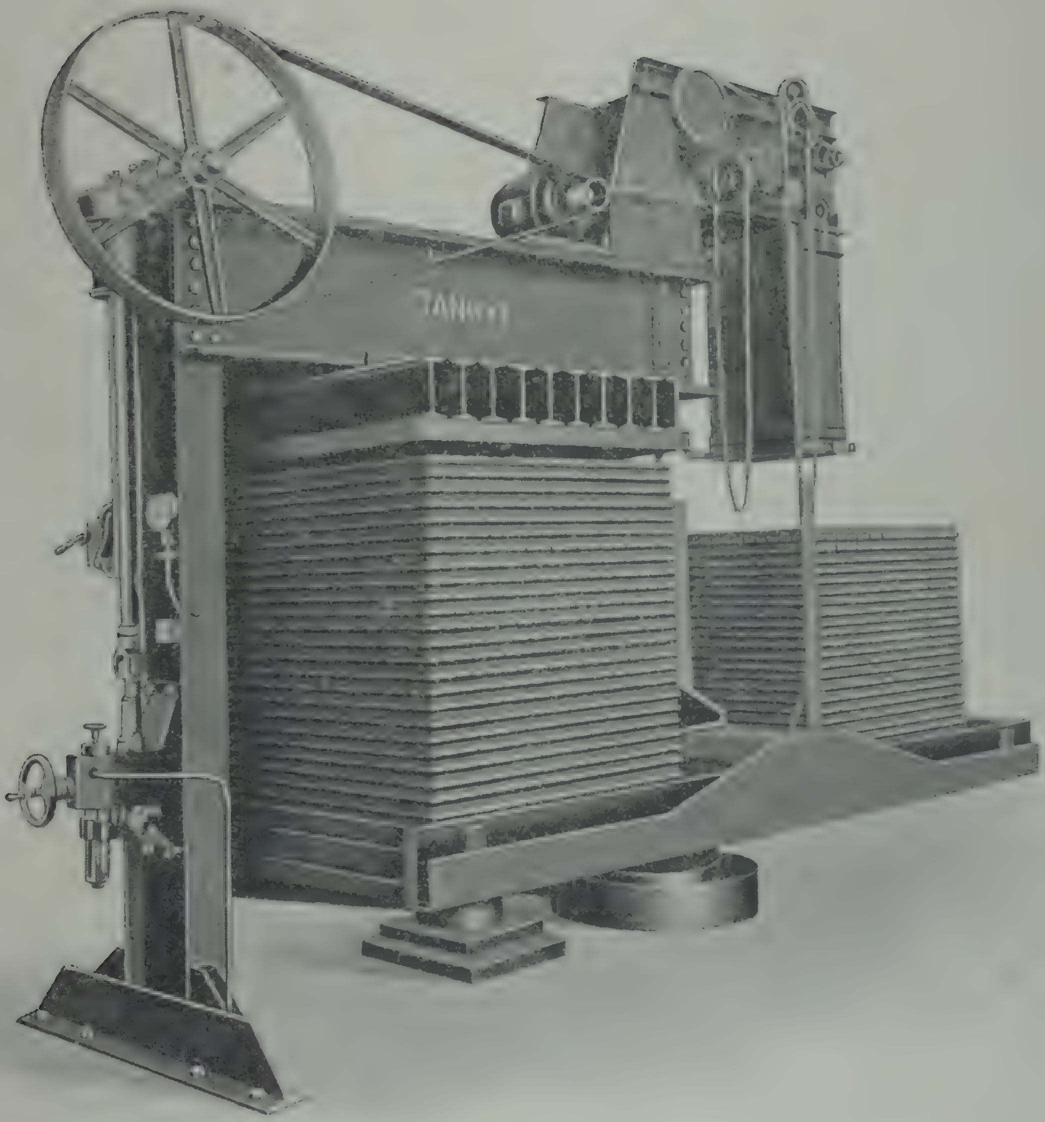

FIG. 5.
Tangye twin-tray rotary press.

rapidly and recovers 80 per cent. of the total juice. The second operation at the highest pressure is timed to coincide with the first pressing on the adjacent press position, but the high pressure is maintained until the appointed time for removing the pressure from both cheeses.

(v) The two men who operate the press are continually employed in discharging the cheeses that have been twice pressed and subsequently building up a fresh cheese. No other duties have to be performed.

The following illustrations of these two types of press indicate their general mode of action.

Fig. 3. Bucher-Guyer three-tray type hydraulic press (each cheese holding 1½ tons pulp at a maximum).
Fig. 4. Tangye three-tray press.
Fig. 5. Tangye twin-tray press.
Fig. 6. Tangye pulp distributor (drum-measurer).

(d) Continuous presses

The search for some alternative method of expressing juice from fruit to the time-honoured practice of building up an erection of racks and cloths filled with milled pulp has proceeded for many years. Only in France have continuous presses reached a stage of development where they have been able to command any considerable degree of acceptance from the fruit processing industry, and even in that country their use is generally confined to the treatment of once-pressed pomace to ease the operation of the pomace drier, or for the preliminary pressing of some fruit prior to application of hydraulic pressure. Several types of machines are available, but for the present purpose it will be sufficient to refer to the range of " Colin " presses.

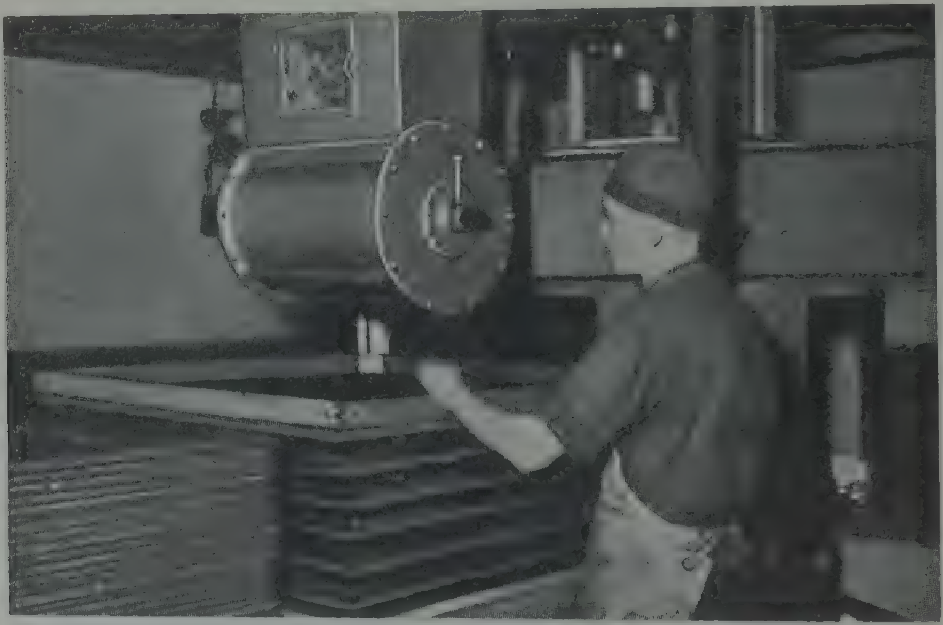

FIG. 6.
Drum measuring device for Tangye apple press.

The machine consists of an outer closed framework within which is housed the actual operating machinery. Two spiral screws, placed end to end and in a contrary sense, rotate in opposite directions within a perforated cylinder. The remote end of the cylinder is closed by a movable metal cone, the position of which can be adjusted to allow more or less tissue to be ejected. The smaller the opening, the greater will be the pressure generated within the cylinder, and the removal of juice will be correspondingly greater. There is, however, a limit beyond which the pressure cannot be allowed to rise without risk of completely stopping the further passage of pulp through the machine. The problem of manipulation thus becomes

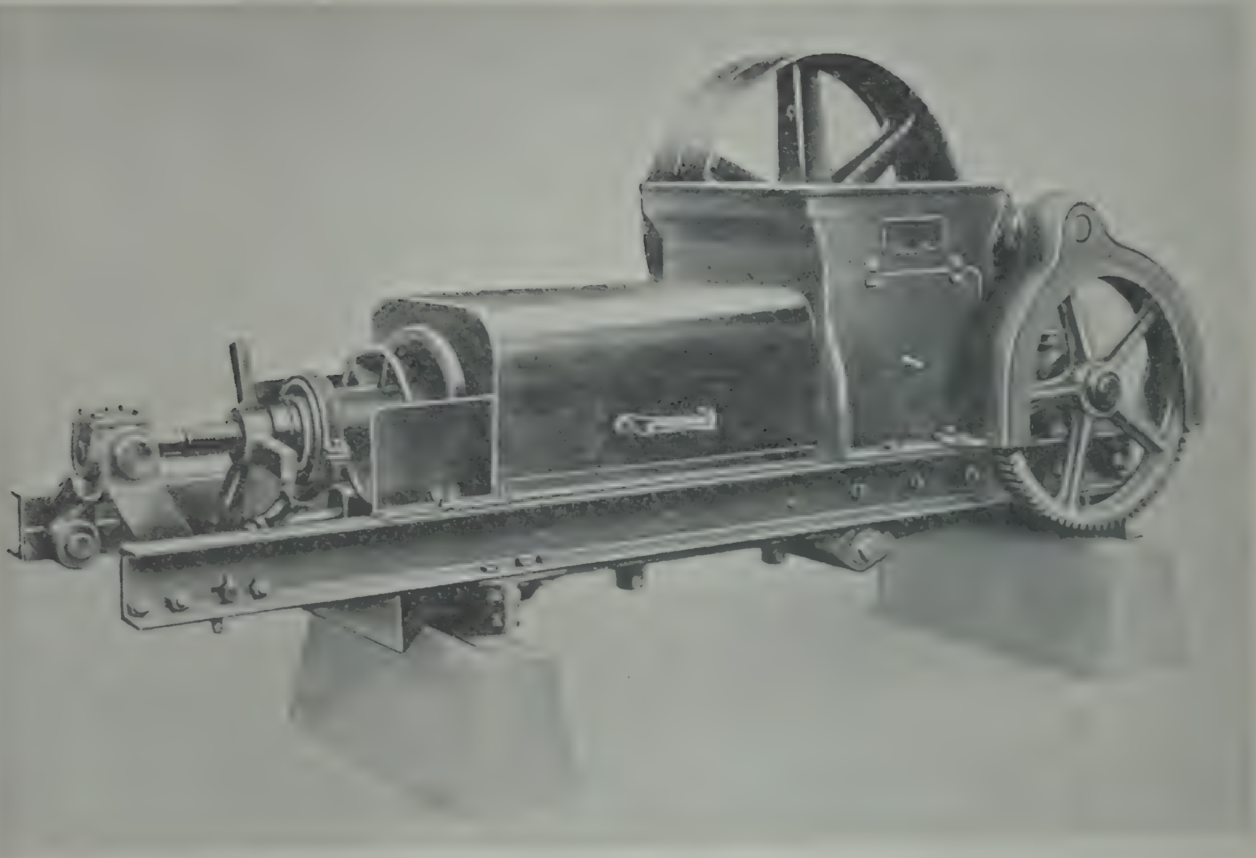

Fig. 7.
Colin continuous press for fruit juices (external view).

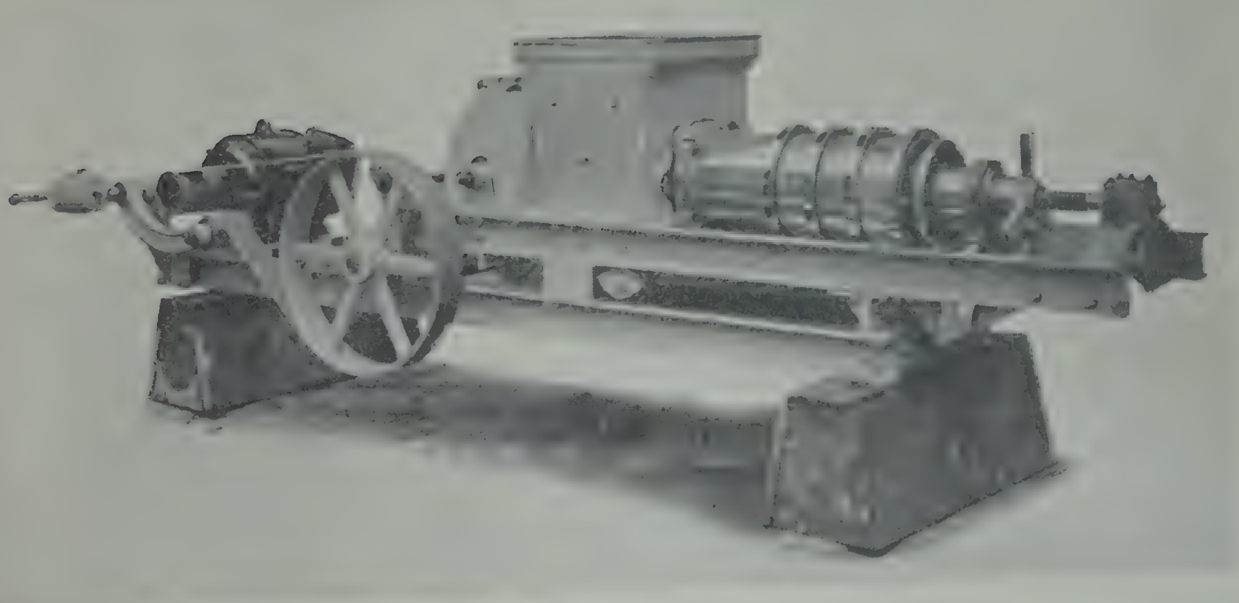

Fig. 8.
Colin continuous press for fruit juices (showing perforated cylinder with movable cone).

one of deciding for each type of material how far the internal pressure can be increased to provide an economical yield of juice without simultaneously so reducing the rate of flow as to affect any advantage that may otherwise accrue.

If one Archimedean screw only is used, the pulp packs tightly and quickly binds into such a compressed mass that movement entirely ceases. The expansion of the idea of the Archimedean screw to include two separate units enables the pulp to move smoothly forward through the machine, being progressively exposed to higher pressures as it approaches the extremity of the second screw. The juice is collected in a vessel of suitable material placed underneath the perforated cylinder.

The various types of Colin press are illustrated in Figs. 7, 8 and 9. Figs. 7 and 8 represent a very modern continuous press specially designed for the production of pure fruit juice—both internal and external views being shown. The machine is made of stainless steel.

A large press suitable for removing some of the residual juice from pressed fruit residues in cider factories and distilleries is illustrated in Fig. 9. It is claimed that its use doubles the capacity of the drying machine and effects an economy of 30-50 per cent. of the steam requirements.

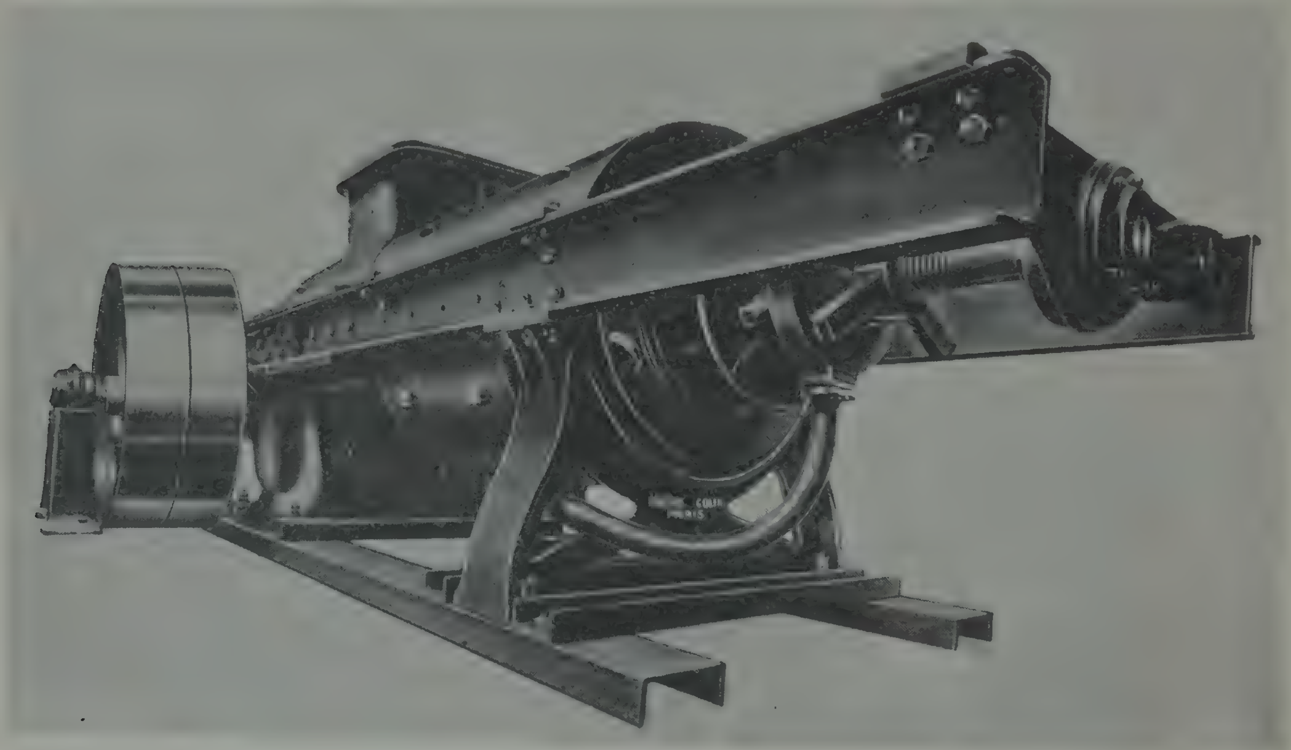

Fig. 9.

Colin continuous press (for treatment of once-pressed pomace prior to drying).

(e) Centrifugation

Some processors have looked askance at the centrifugation of fruit juices on the ground that they introduce a danger of aeration which is at all costs to be avoided if full flavour retention is to be attained. The Sharples Supercentrifuge, which proved its usefulness in the earlier years of the development of scientific cider-making in England and France, was not free from the suspicion that its use on fruit juices might entail some incorporation of air, but a new model has very recently been introduced which operates continually under an atmosphere of carbon dioxide. Fig. 10 shows the latest type of this machine. Such a centrifuge is extremely useful when considerable amounts of suspended solids present in a juice would otherwise need to be removed by a filter of some description. The use of a centrifuge, whilst seldom giving complete clarity to a juice, does very considerably lengthen the life of the filter pack and is thus effective in aiding the efficiency of production.

(f) Juice storage

European practice in the past ten years has favoured bulk storage in large tanks under carbon dioxide pressure. There has, however, been one most important addition to the Böhi process, due largely to the very heavy costs entailed in the purchase of steel tanks to withstand the 120 lb. pressure necessary for storage at normal temperatures. If the tanks can be installed in a room maintained at 0-2° C., 45 lb. pressure of carbon dioxide per square inch is sufficient to inhibit fermentation, and this has now become a favoured procedure, especially in countries where steel is in very short supply. The linings for such tanks are legion, but reference can be

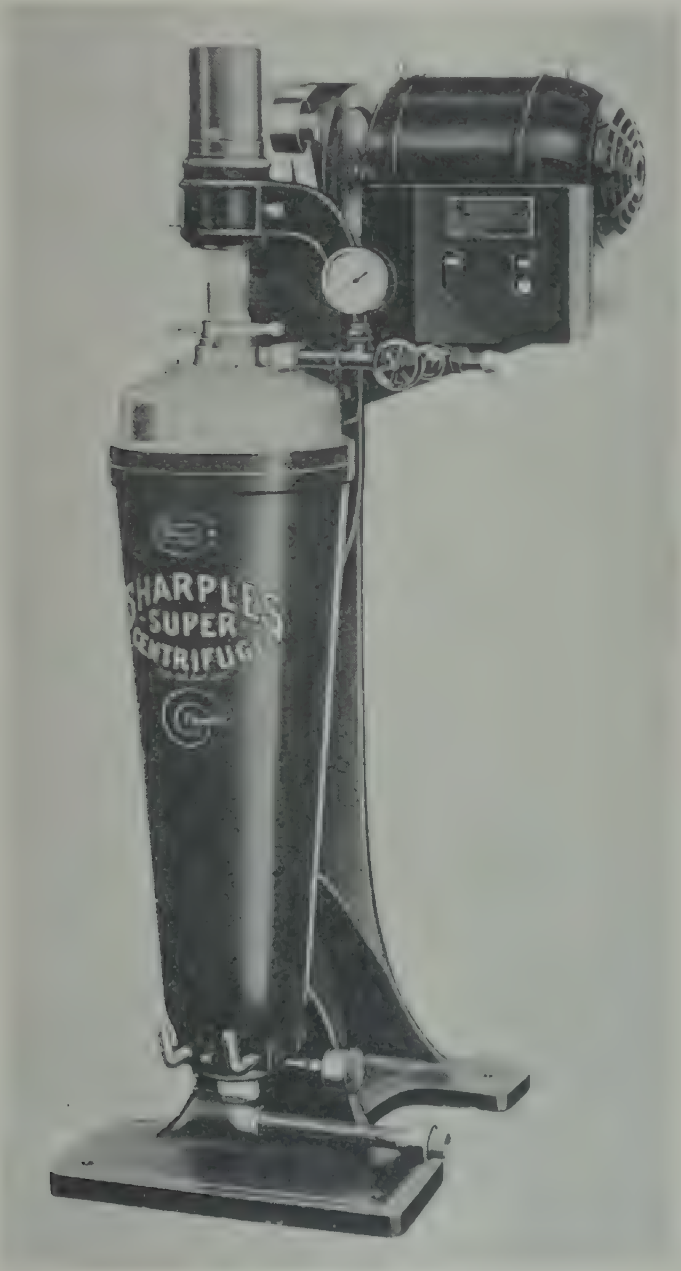

FIG. 10.
Sharples supercentrifuge with CO_2 connection.

made here only to Nutraline, Lithcote and Prodor-Glas. The last-named, apparently as a result of successful application to installations for juice storage in England and Holland, is being applied on a large scale to tanks in Switzerland—the actual home of the Böhi tank. Fig. 11 shows a large installation of forty-four 5,000-gallon low pressure tanks for juice storage in a new British factory, in which the tanks are Prodor-Glas lined and are contained in a room maintained at 0-2° C. This development, apart from saving steel, has the additional advantage of retarding flavour changes in the juice and when using full Swiss technique of cooling the freshly expressed juice from an ambient temperature of 15-17° C. down to 8° C. within a short time of pressing the fruit, juices can be stored with an absolute minimum of oxidation.

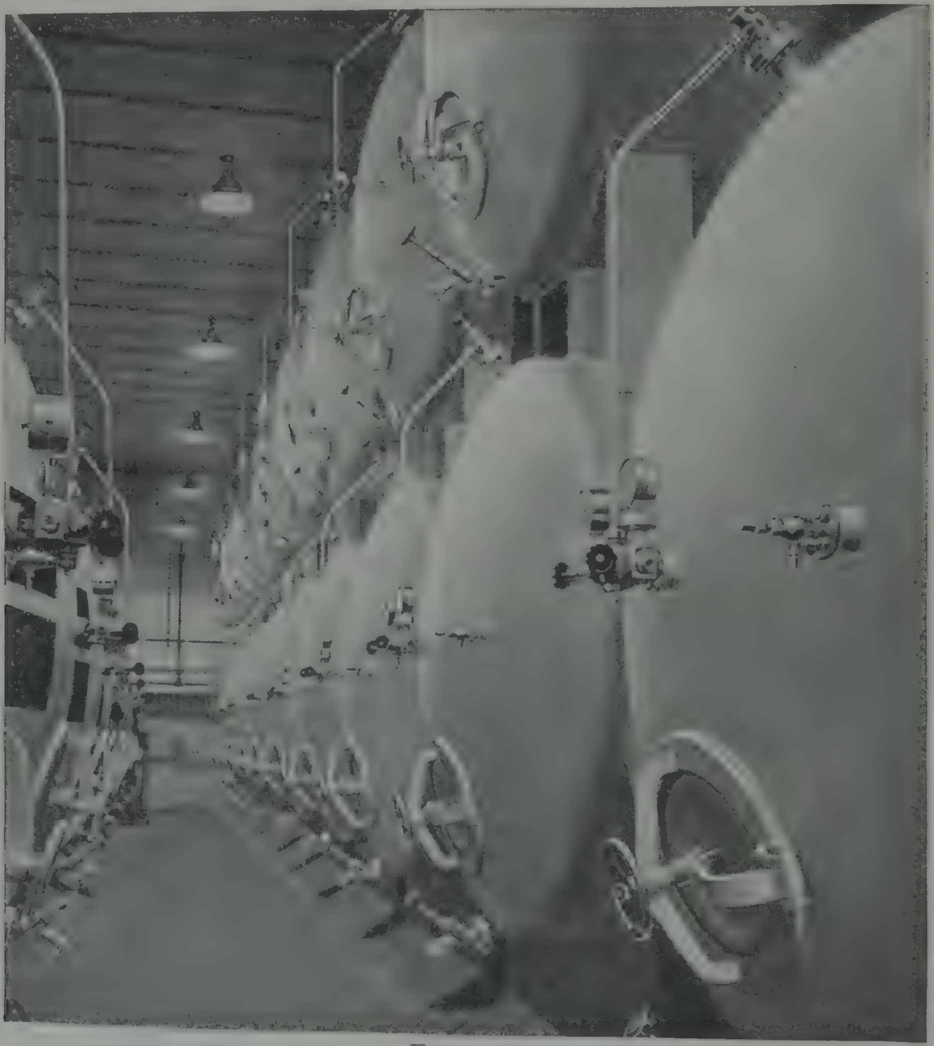

FIG. 11.
Prodor-Glas lined low pressure tanks.

The latest type of plant for impregnating the carbon dioxide into the juice, prior to its reception into the storage tanks, is the Sulzer machine (Fig. 12). The tanks are first filled with water which is then removed by carbon dioxide pressure. (The virtual absence of air is essential for the ultimate freedom from fermentation and fine flavour character of the juice.) The required pressure of gas is built up in the tanks and the Sulzer machine is then lined up to impregnate this gas into the supply of juice in a continuous manner, and to force this impregnated juice into the tank. The oxygen content of the gas above the liquor level in the tank must be continually tested, and must not rise above 2 per cent. This process undoubtedly provides the most satisfactory method of storing juice in bulk and if it is combined with cold storage conditions the flavour improvement over storage at normal temperatures is remarkable.

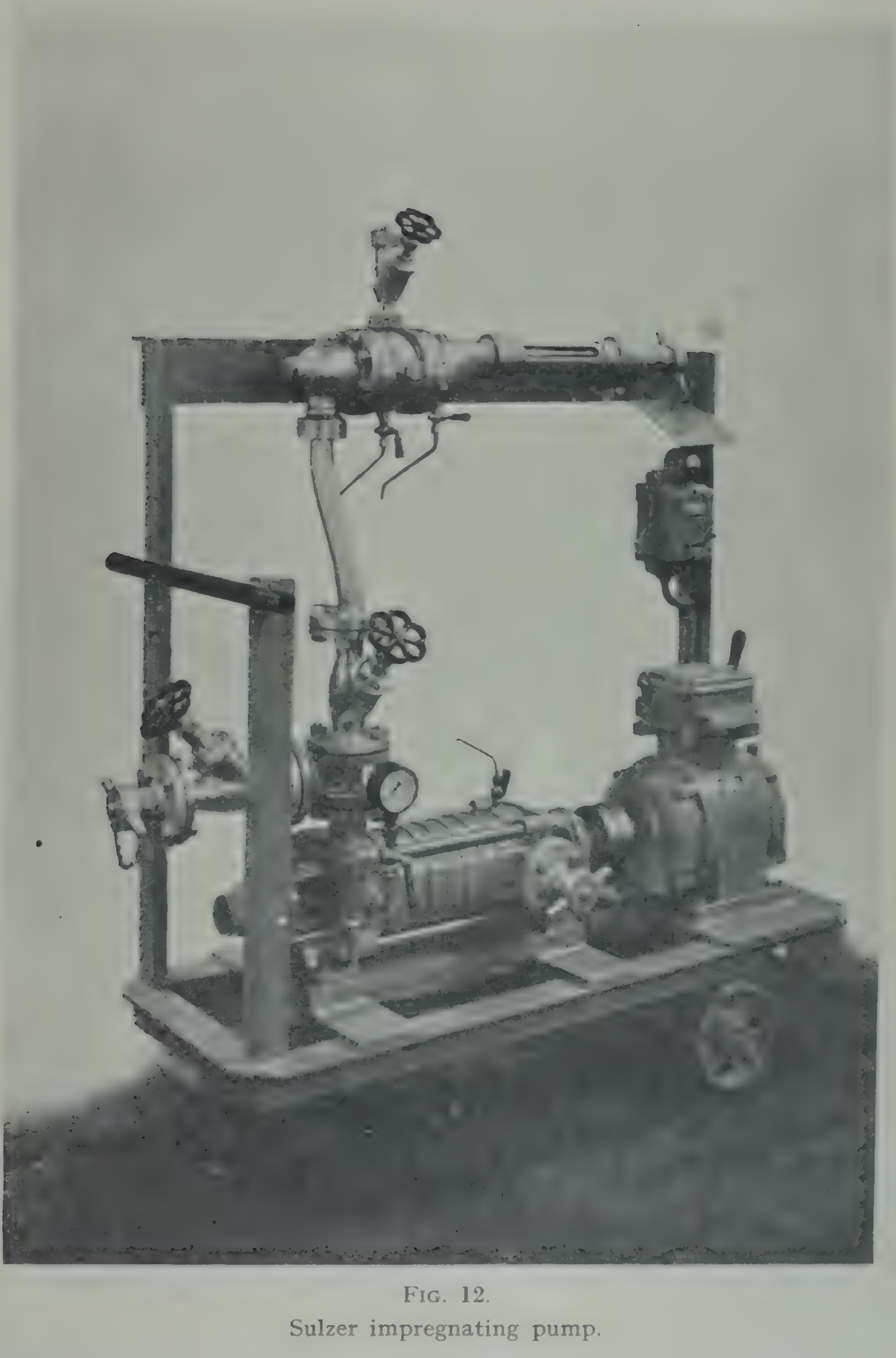

Fig. 12.
Sulzer impregnating pump.

It is worthy of mention that there is some difference of opinion between American and European technicians regarding the most suitable flavour for apple juice. The former hold the opinion that there is no flavour better than that of the fresh juice as it runs from the press, and every effort is made to retain the juice in that condition. Continental experts, however, tend to regard a certain degree of maturity of flavour as an essential feature of the process, and although the low temperature storage might be regarded as retarding such maturing processes, it is a fact that even at low temperatures the flavour of apple juice will mellow over six months and the "green" character of the fresh juice will completely disappear.

The storage of juice by pasteurization into large vessels is no longer practised, but a certain amount of juice is still preserved in the smaller factories by flash pasteurization into 5-10 gallon glass vessels. In view of the possibility of the development of haze or deposits, it is not safe to use bottles or cans as a means of storage for clear fruit juices until a reasonably protracted period has elapsed for the stabilization of pectin and protein constituents.

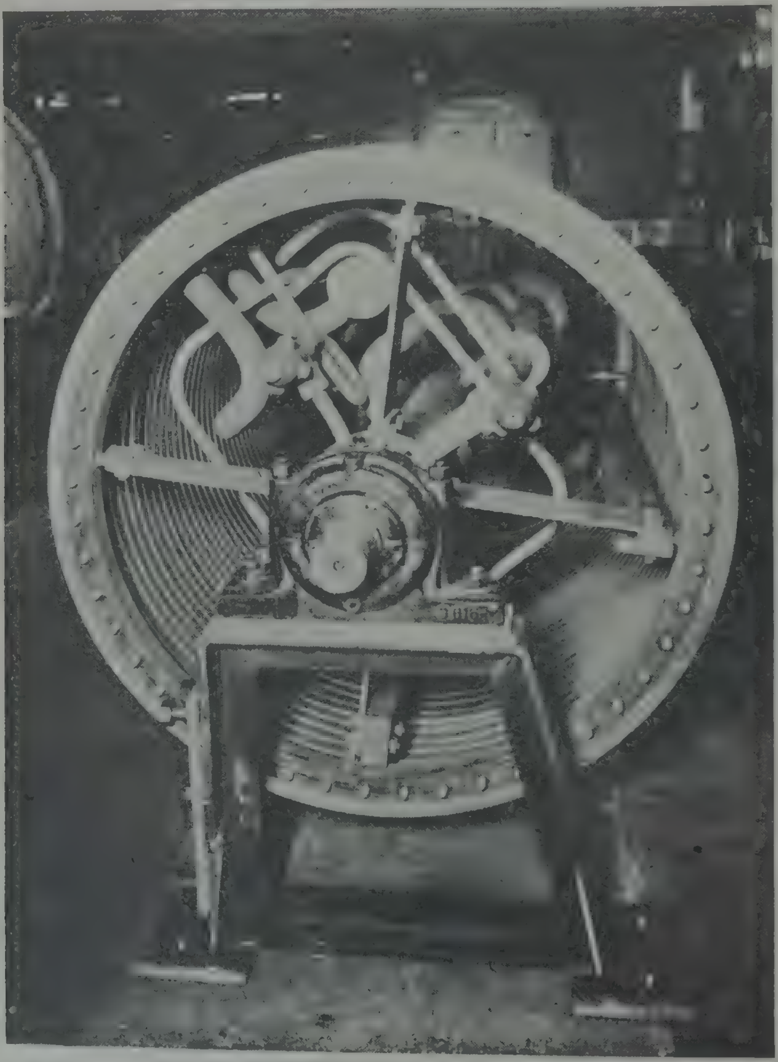

FIG. 13.

Escher Wyss freezing drum for fruit juices.

(g) **Storage of juice in frozen condition** (Escher Wyss system)

During the Second World War the provision of steel tanks for the Böhi method of storage became difficult and efforts were made in Switzerland to introduce an alternative. The firm of Escher Wyss eventually developed a process for freezing the juice into a solid form and the reception of this frozen mass into large silos maintained at a very low temperature of — 25° C. The process was jointly investigated by the firm concerned, and Professor Columbi of the Engineering Faculty of Lausanne, the final installation being established at the Cidrerie Pomdor at Yverdon. The refrigeration was accomplished by the "Frutasco-Gèle" system. This was capable of cooling 10,000 gallons of fresh juice daily from 20° C. to 2-3° C. and maintaining it at this temperature. The plant could also freeze 8,000 gallons of cold juice per day, the frozen juice being stored in silos at very low temperatures. Figs. 13 and 14 show the internal arrangement of the freezing drum and the machine in actual operation. Up to one ton of frozen juice could be produced hourly. The transport of the frozen juice was easily undertaken in specially constructed vessels.

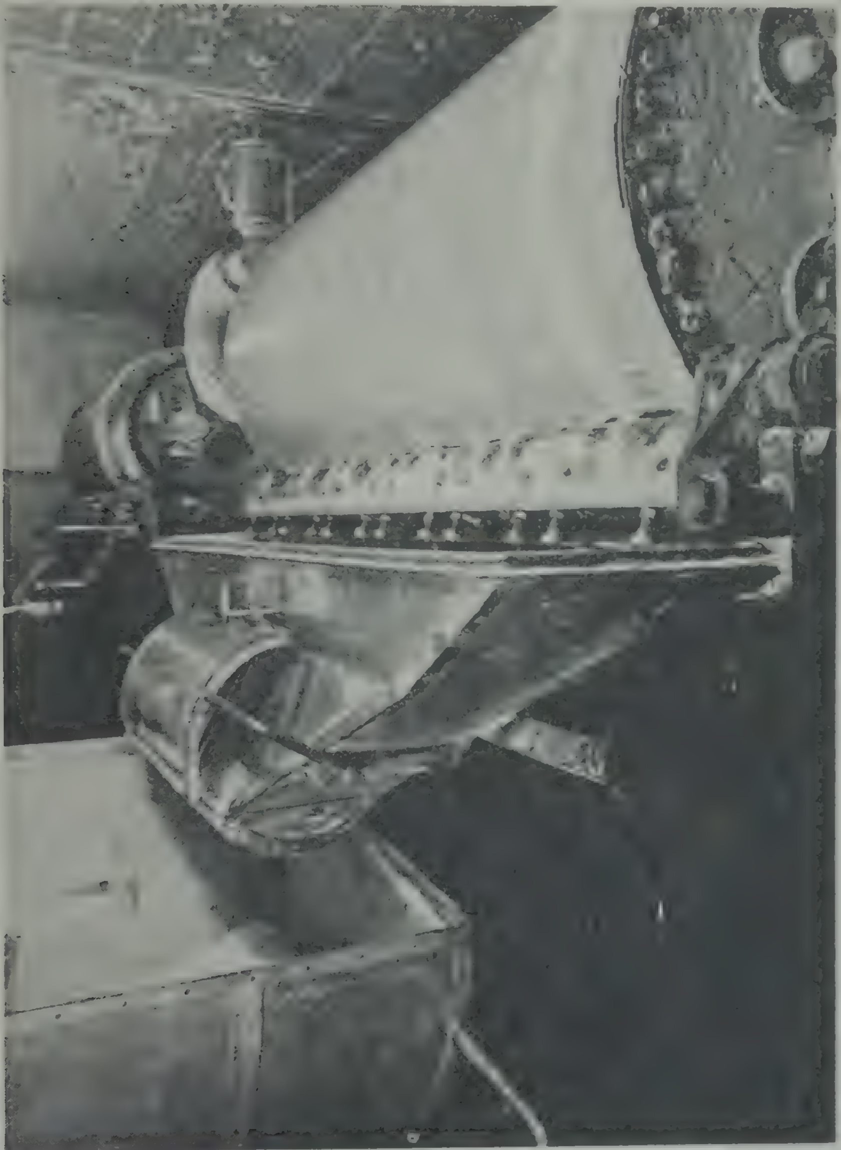

FIG. 14.

Escher Wyss freezing drum in operation on fruit juices.

The layout of the process is shown in Fig. 15. The numbers refer to the following features :

1. Rotasco compressor.
2. Condenser.
3. Apparatus for freezing juices.
4. Air cooler.
5. Refrigerating plant for cooling silos by circulation of cold air.
6. Frozen fruit juice.
7. Ducts to carry warm air to the foundations to prevent freezing where it is undesirable.
8. Low temperature store.

(h) Sterile bottling of fruit juices

The previous Technical Communication gave considerable prominence to the cold filling of fruit juices by the Seitz aseptic technique. The procedure was regarded by many technicians who favoured the simpler and cheaper pasteurization method as being unsuitable for the bulk trade. Hence, it is interesting to read the eulogies of the cold process that have been expressed by investigators from American and British official sources when studying the German fruit juice industry in 1946-7. There can now be no possible doubt that the cold, sterile filling of fruit juices represents the finest process that exists at present for the preparation of quality products. The incidence of fermentation becomes negligible when this process is used. Fig. 16 shows a very modern sterile bottling unit installed in Holland by a British firm. The high walls are tiled to ceiling level, the partition walls are constructed of enamelled steel and glass, whilst the ceiling is painted. The room is maintained under a positive pressure of sterile air, but air locks should preferably be arranged at all doors leading out of the bottling room.* The

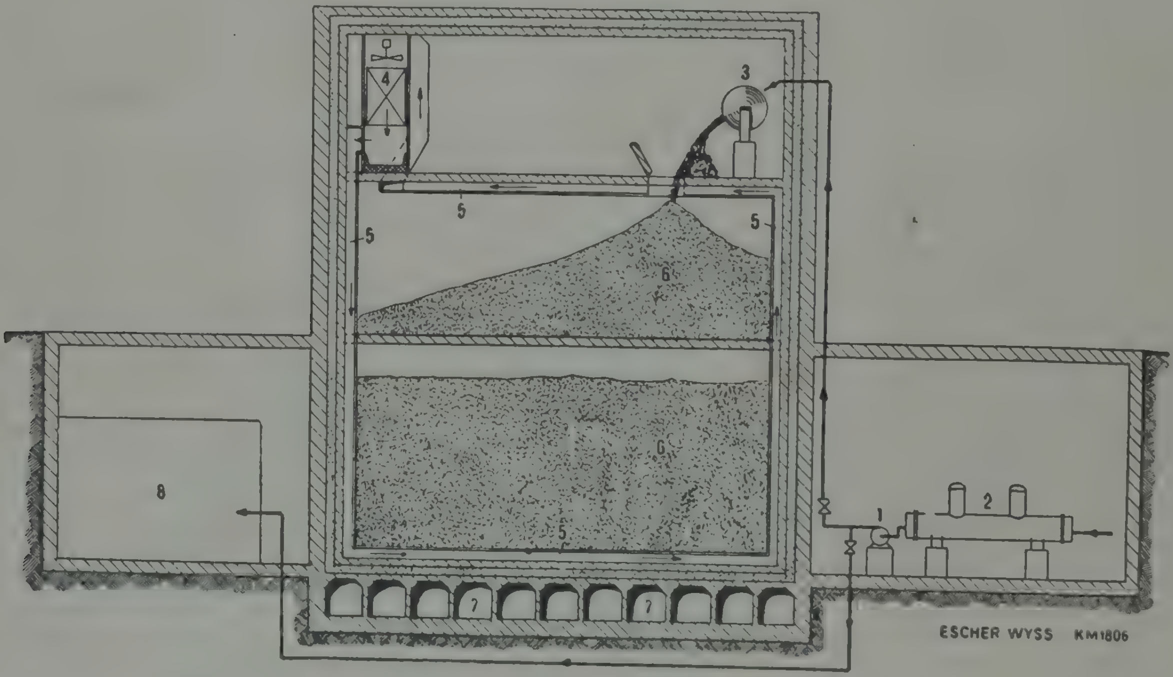

FIG. 15.

Escher Wyss system for storage of frozen fruit juices.

* Air is sterilized either by passage through a sterilizing filter, or by passing it through a 20 cm. column of tile rings against a powerful spray of water.

Carlson 24-head pressure filler, fitted with a rotary crown corking machine, is designed to give a completely sterile fill, and data obtained with this machine indicate the efficiency of the process. For the stability tests, all bottles were kept for three months and inspected after that period. The results are given below:

Production (bottles)	Rejects	Rejects as percentage of production
20,664	14	0·07
19,394	14	0·07
12,456	21	0·17

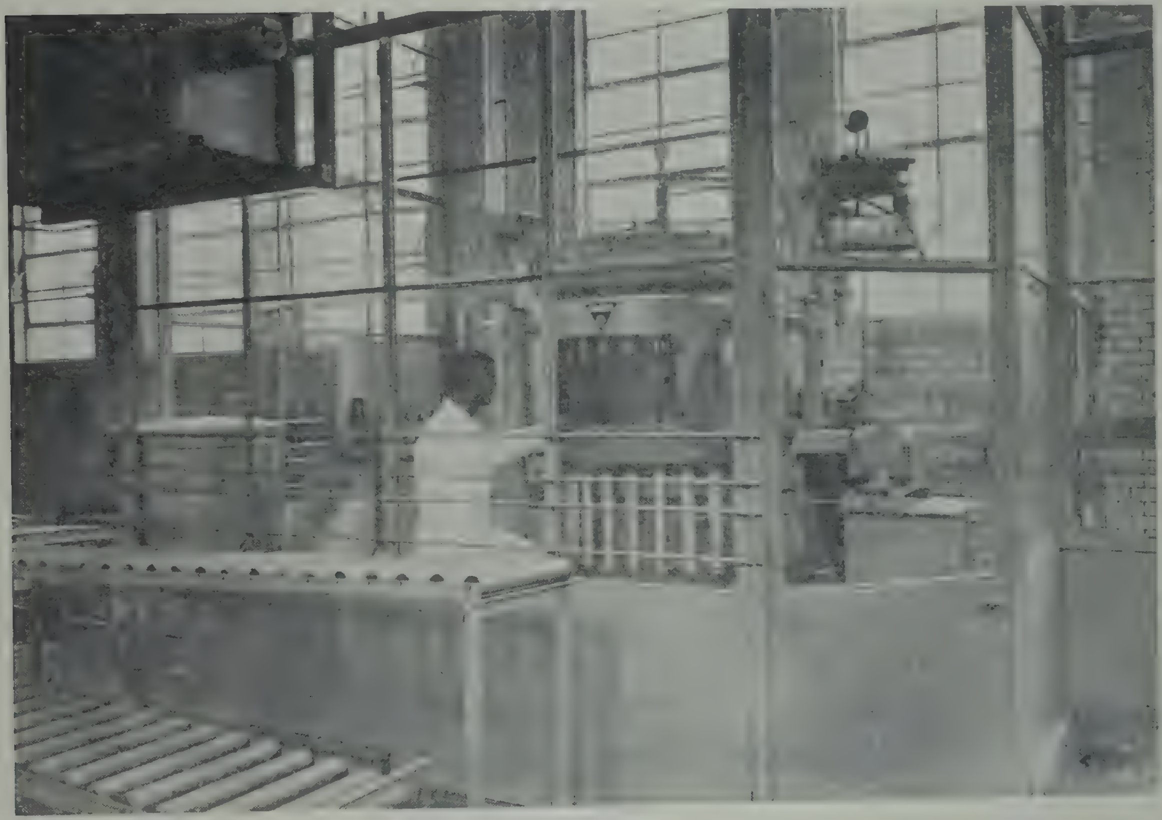

FIG. 16.

Carlson 24-head pressure difference filler with special rotary crown corking machine used in filling fruit juices (in sterile room).

The sterilization of the bottles, apart from their initial cleaning, is effected by steam and final rinsing with sterile water, this water being freed from organisms by filtration. Fig. 17 illustrates a bottle washing machine for fruit juices, used in conjunction with the plant in Fig. 16.

In view of the general preference of the public for a sparkling fruit juice, with say 7-10 lb. carbon dioxide per square inch, it becomes necessary to deal throughout the bottling process with an aerated juice, and conditions of temperature and pressure must be carefully watched to ensure a sufficient residue of gas in the bottled product. Flash pasteurization is not capable of adaptation to sparkling juices at the present time, although there have been suggestions that the process has been successful for the bottling of carbonated beers. Such pasteurization as is carried out is almost entirely done in bottle, using continuous pasteurizers which, for apple juice, maintain the product at a temperature of 68-70° C. for 20-30 minutes.

(j) Sale of fruit juices in containers

The Swiss and German fruit juice factories have raised to a high pitch of efficiency the sterile filling by the cold process of fruit juices into 5-8 gallon containers which are sent to sales points in cafés, hotels, hospitals, railway stations, etc. The juice dispensed from such vessels is almost always kept at a few degrees above 0° C. and is consequently not exposed to heat at any stage of the processing. The infection of the juice by yeast is likely to arise largely at the points where the container is fitted to the pump and dispensing system at the point of use, but simple connections have been devised to enable this process to be satisfactorily carried out without loss of sterility. The cold juice distributed in this way is in great demand from hospitals in Switzerland and Germany, whilst the first scheme for its widespread distribution in England was commenced, with considerable success, in 1948.

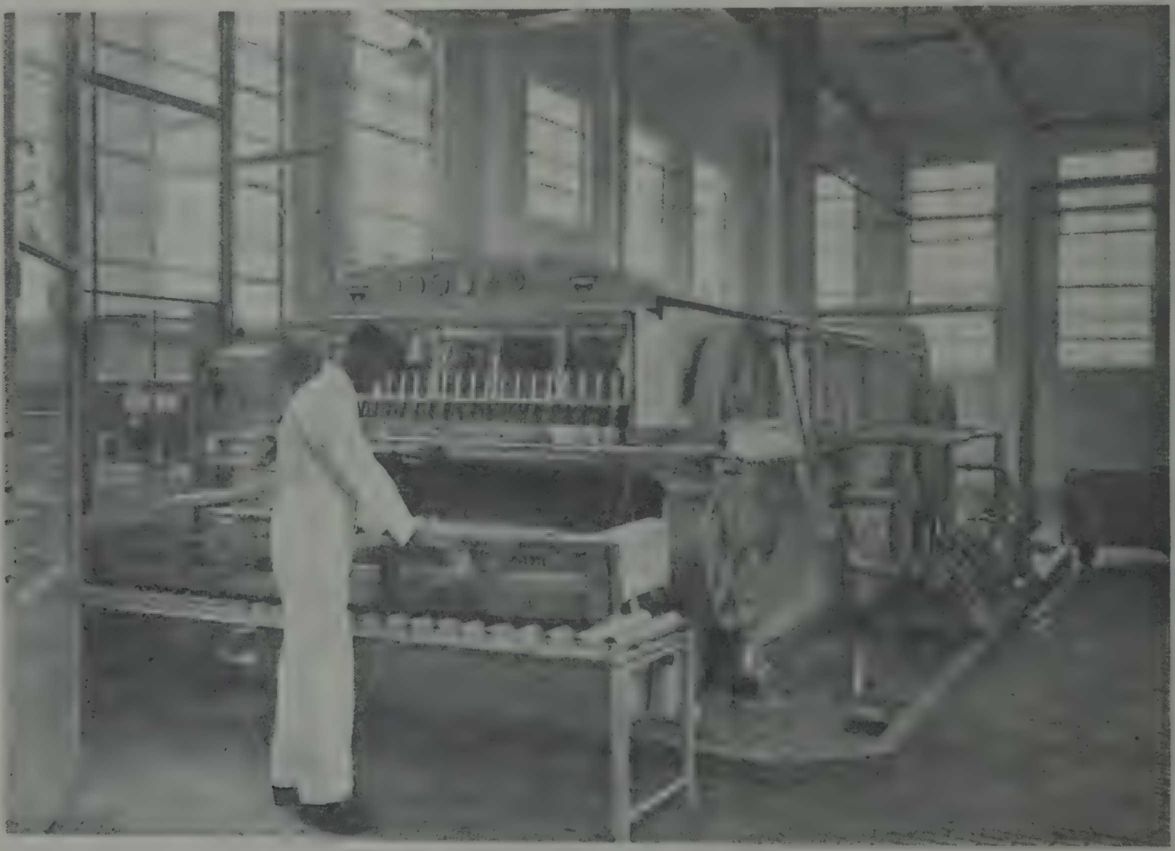

FIG. 17.

Carlson B.S.T. bottle washing machine.

(k) Bottling machines

Improvements in design in bottling machines in recent years have very largely been due both to the importance of achieving the utmost efficiency in the bottling of beer and to the natural desire of the bottling equipment makers to examine the specific problems inherent in the treatment of still or carbonated fruit juices. Such subjects as adequate sterilization of the filling head and valves have received detailed attention, and whilst few new fundamental principles have been evolved, very great improvement in efficiency, speed and sterility has been achieved in recent years. Many excellent bottling machines are on the market, either primarily

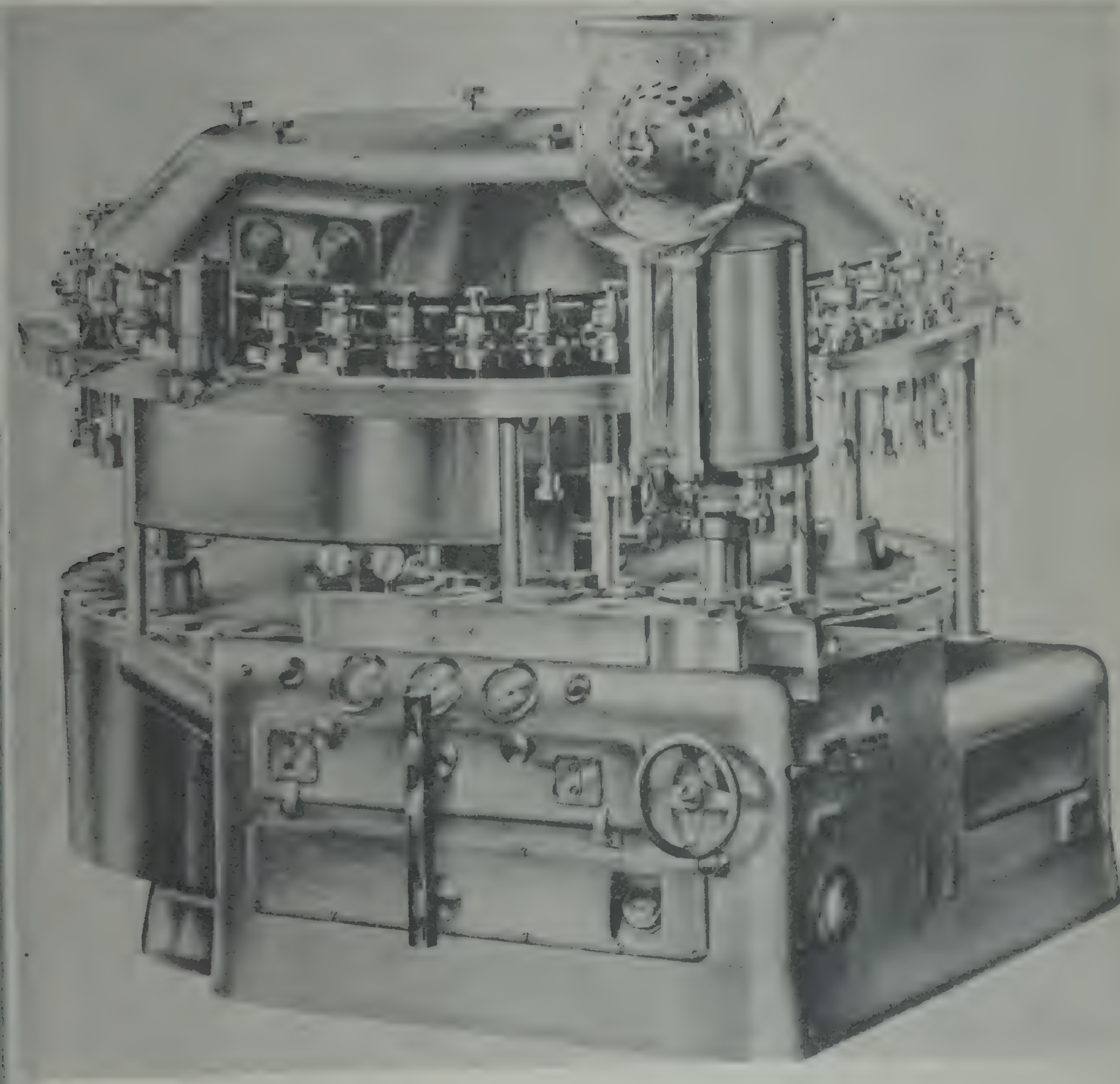

Fig. 18.
Adlam filling machine for fruit juices.

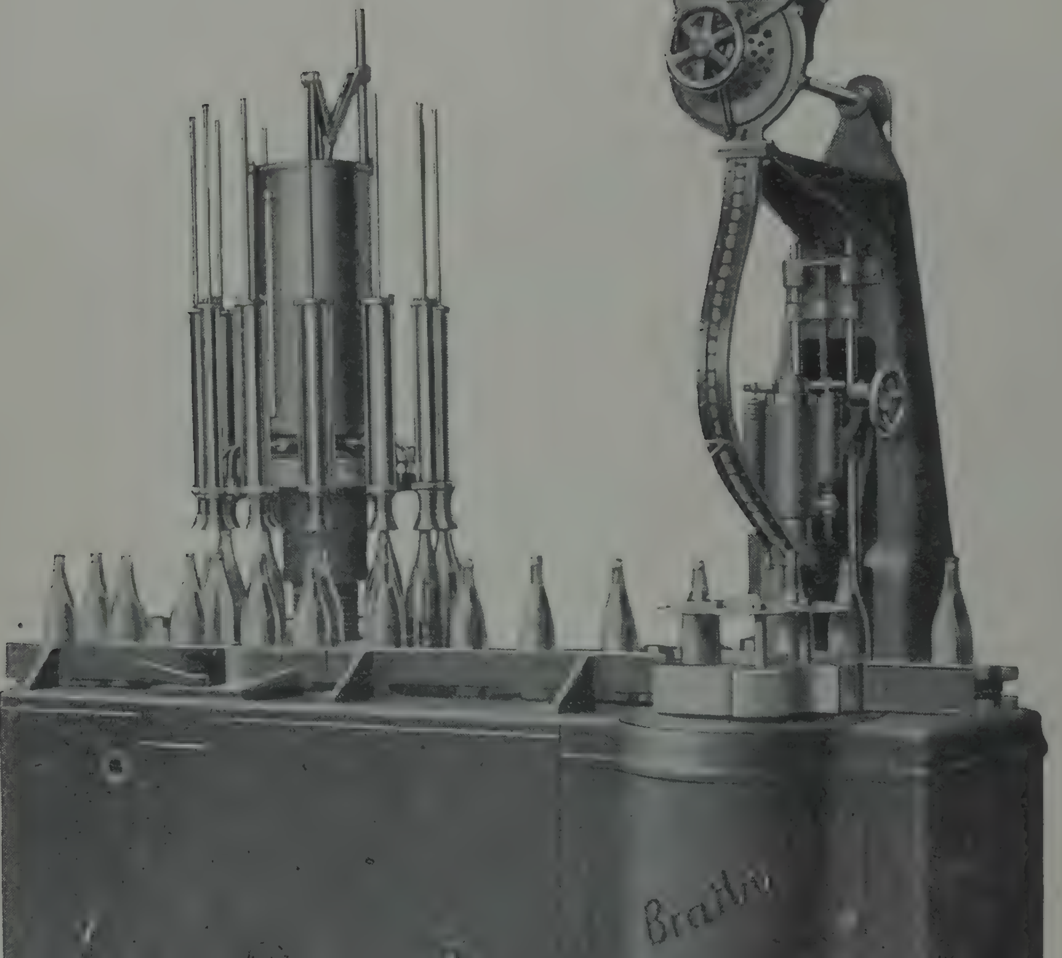

FIG. 19.
Bratby & Hinchliffe bottling machine.

lesigned for beer (e.g. the Adlam machine) or those specifically developed for use with fruit uices. Three of these types are briefly described and illustrated here. Fig. 18 shows the dlam 40-head automatic filling machine and crowner. The bottles are filled by siphon action nder pressure. The juice in the tank lies exactly level with the bottles, and the level of the uice can be controlled to within $\frac{1}{8}$ inch by means of a dual photo-electric cell. The whole lant can be sterilized efficiently and with ease. The filling heads are simply constructed with horizontally rotated, armed disc working between two joint faces of special composition which an be sterilized by low pressure steam. This machine is entirely constructed in stainless steel nd represents a very able contribution to fruit juice bottling technique.

A further recent addition to bottling plant is that of Messrs. Bratby & Hinchliffe, one nodel of which is shown in Fig. 19.

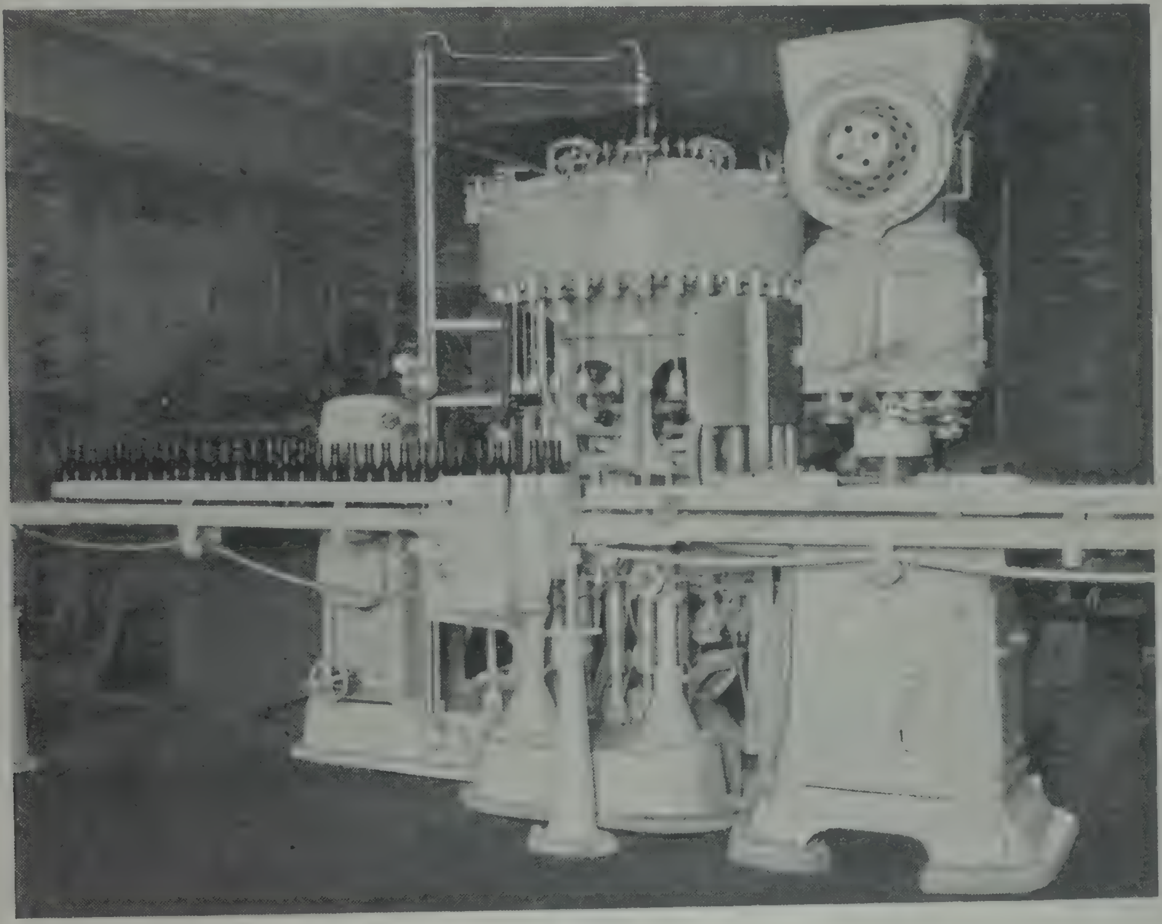

Fig. 20.

Liquid Carbonic Company 32-head beer filler and 8-head crowner.

This 12-head automatic filling machine for fruit juices uses a positive measuring system to deliver a definite quantity of juice into each bottle. A feature of the latest construction is the provision of all stainless steel contact with the product. The machine can be provided with a Bratby & Hinchliffe crowning unit which is available with interchangeable heads to deal with cap tightening, screw-stopper tightening, crown corking or cork pressing as required.

Finally, there is the system of the Liquid Carbonic Company Ltd., illustrated in Fig. 20. The machine depicted is a 32-head beer filler and 8-head crowner. It is fully automatic with a rated capacity of 300 dozen half pint bottles per hour and accessories can be provided to handle a full range of bottle sizes.

This machine works on a special low pressure filling system, designed to afford high efficiency by ensuring the full gas content of the liquid in the bottle, accurate filling heights and no wastage due to broken bottles. The filling valves work on a diaphragm principle with a closure at the end of the filling tube entirely free from mechanical wear. The raising arms are mechanically operated with a special latch system which prolongs the mechanical life of the machine. New types of washers, sealing rubbers and diaphragms are now available so that the machine can be thoroughly sterilized with low pressure, raw steam.

(l) Filters and filter media

Whilst the many types of filters in use in 1938 are still extant, there have been improvements of design in the machines themselves and very considerable advances in the manufacture of the filter media used. Diatomaceous earth filters are not widely used for apple juice, for there is a feeling in Switzerland that the flavour of the juice is slightly impaired by contact with this type of material. The cotton-asbestos sheets which were developed by the Seitz firm of Kreutznach in Germany before the last war were not available outside Germany during the war years, and British firms were faced with the problem of making their own supplies, not only for the filtration of beer, cider and fruit juices, but also for the sterile filtration of blood serum for the Blood Transfusion Service. It must be regarded as a matter for legitimate pride that British firms were able, very early in the War, to provide a series of filter sheets of varying efficiencies for yeast removal which were of the greatest possible service in the particular field for which they were so urgently needed. A sterilizing filter is shown in Fig. 21, whilst the range of filter sheets that is now obtainable can be seen from the accompanying table of the products of Messrs. T. B. Ford & Co. Ltd.

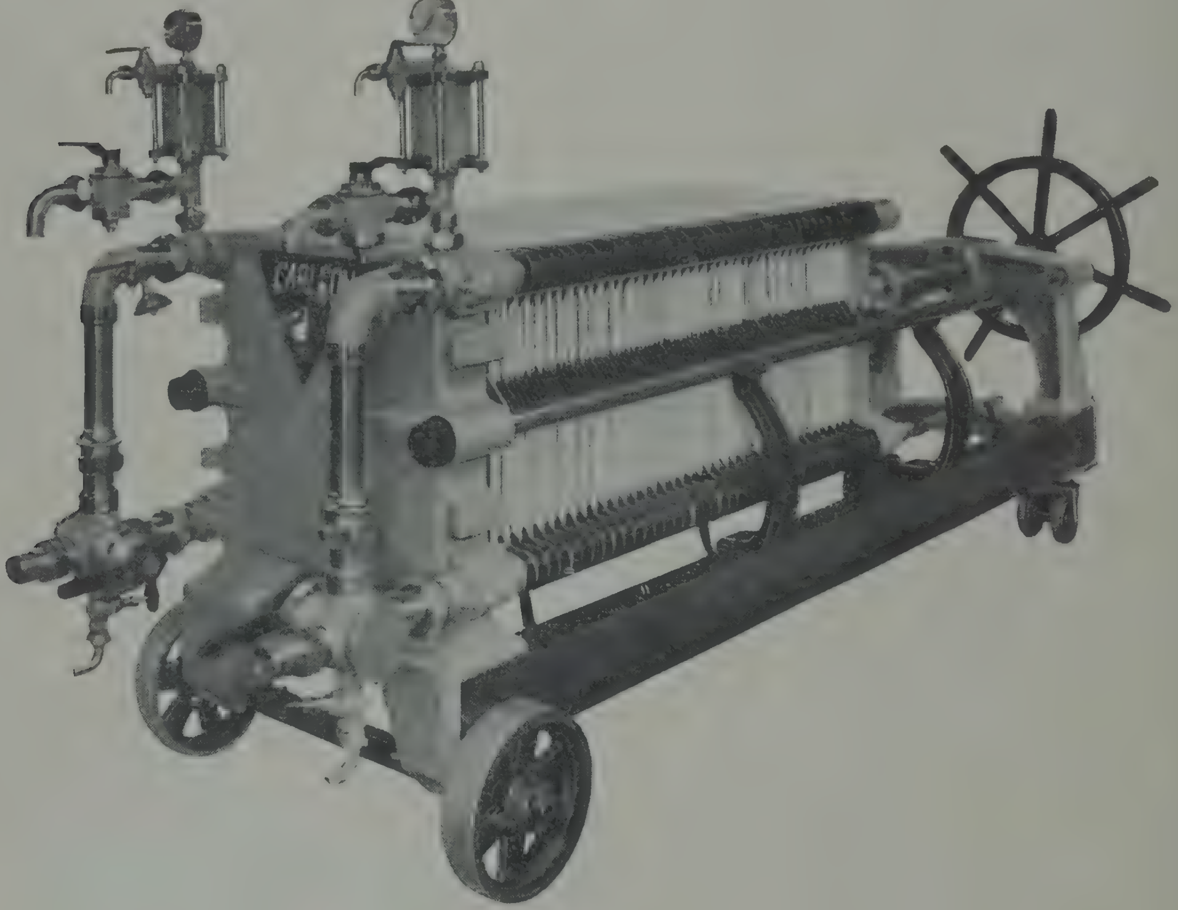

Fig. 21.

Carlson 60 cm. fruit juice filter.

STERILIZING GRADES

Grade	Resistance to Bacteria and Yeasts	General Description and Uses
SB	Complete.	For perfectly pre-filtered liquids containing very small micro-organisms. For serums, etc.
S/GS/1	Down to removal of *B. prodigiosus*.	For perfectly bright liquids containing little or no unstable colloidal matter. Ideal for beers, cider, etc.
GS	General aeriform bacteria.	Excellent rapid filter for vinegar, food extracts, etc., for general sterilizing.
GSB	Most aeriform.	Rapid filter of sterilizing type.
AIR		For air sterilizing.

CLARIFYING GRADES

Grade	Resistance to Bacteria and Yeasts	General Description and Uses
S/FC/2	Removes yeasts and spores of yeasts.	Extremely fine clarifying mat.
S/FC/1	Removes yeasts and spores of yeasts.	General clarifying mat removing yeasts and precipitated colloidal matter. Ideal for clarification of beers, cider, etc.
FC	Removes yeasts and spores of yeasts.	General clarification where speed and brilliance are more important than positive yeast spore removal from easily filterable liquids.
FCB	Removes yeasts.	A rapid fine clarifier for use where speed is essential.
CC/01		A rapid filtering mat; suitable for pressure or gravity filters.
CC/02		A somewhat more rapid mat, similar to CC/01.
CC/03		A very rapid coarse filter mat eminently suitable for liquids where speed and a finer degree of filtration than is given by CC/04 are required.
CC/04		Eminently suitable for viscous liquids, e.g. oils, syrups, etc.
CC/NA		A very fast filter mat with special uses, e.g. food extracts, etc.

GRADES SPECIALLY MANUFACTURED FOR WINES, SPIRITS, CORDIALS AND FRUIT JUICES

Grade	General Description and Uses
SL	General sterilization of perfectly bright liquids containing no unstable colloidal matter.
C7	Extremely fine clarifying mat.
C5	General fine clarification; removes yeasts and spores of yeasts, imparting a brilliant polish to the filtrate.
C4	A rapid fine clarifier which will remove yeasts.
C3	General all-purpose filter mat.
C2	A very rapid filter mat, eminently suited for liquids where speed is essential.
C1	One of the fastest filter mats available.
CO	A fast filter mat with special uses.

(m) Soft fruit juices

The heat treatment for the extraction of juices from soft fruit still holds sway in U.S.A., Canada and Holland, but in England and Switzerland the cold process, using pectic enzymes on the milled fruit, is preferred. With increased commercial enzyme potency, the removal of pectin has become a more straightforward matter than was the case ten years ago, and during the last War very large quantities of high quality blackcurrant juice (for subsequent processing into a high vitamin C syrup) were prepared for the Ministry of Food by a cold process in which Pectinol M and, latterly, Pectinol 10 M, were found to be very satisfactory for removing the pectin and reducing the viscosity before any danger of fermentation occurred. The storage of these juices under carbon dioxide pressure and at low temperatures has been followed by exceptionally good flavour and vitamin C retention.

Details of the alternative process have been provided by Atkinson and Strachan (contributors of the following Chapter) and are given here *in extenso*:

" Laboratory experiments on extraction at Summerland and Ottawa have favoured two different, although closely related, methods.

" For extracting blackcurrant juice a German process was found quite simple and efficient by the Summerland laboratory in 1939. This process consists of heating the fruit in a perforated container in an atmosphere of steam. The fruit cells are burst by the heat and the juice drips into a lower container. It is best to lay clean, light, factory cotton in the perforated container to prevent pieces of fruit falling into the juice. The top of the fruit should be covered with a light piece of acid-resistant metal to prevent condensed water from dripping on the fruit. The layer of fruit should not be more than 6 inches deep, and the currants are heated for 30 to 60 minutes. The remainder of the juice available can be obtained by pressing the pulp. The two lots of juice may then be mixed. The amount of sugar added is dependent on the variety of fruit. Boskoop blackcurrant juice has sufficient flavour so that it can be diluted with two volumes of water to one of juice. The resulting product should have 15 to 16 per cent. tota soluble solids (mostly sugar). Thus, if this juice is to be canned ready for dilution, it should have a soluble solids content of 45 per cent. This amount can be approximately determined with a Balling hydrometer and should be more accurately checked with a refractometer.

" Where equipment is not available for steam extraction, the juice may be removed by heating the fruit to 180° to 185° F. in a steam jacketed kettle, followed by pressing. Small quantities of water are usually added to the fruit to prevent scorching. After pressing, the pulp may be mixed with an equal weight of hot water and pressed again. The two pressings are mixed together, strained and sweetened as previously described. The steam extraction method is preferred as a better flavour is preserved, the juice is clearer and extra water is not needed.

" Arengo-Jones, on the other hand, also writing in 1939, recommended a blanch and press extraction as follows :

" ' For juice preparation the currants should be harvested when fully ripe, under-ripe fruit having too much astringency and lacking flavour. A " strigger " should be used to remove the fruits from the stems as this does not damage them. The cyclone type of machine pulps the fruit and exposes it to rapid oxidation.

" ' Various methods of juice extraction may be employed, but the heat method is preferred at this Laboratory. The fruit may be pulped and immediately heated, or the whole fruit can be heated in a steam jacketed pan with a small amount of water (about 20 gallons per ton) and, in either case, heated to 165° to 170° F. Following a holding period of about 5 minutes, the pulp is ready to press. Due to the slimy consistency of this fruit and the large amount of pectin it contains, the juice does not press out readily, but 3 per cent. by weight of a coarse filter aid such as Celite 503 thoroughly mixed with the pulp just before pressing will overcome this difficulty.

" ' As soon as the juice has cooled to below 120° F. it is treated with pectin-decomposing material such as Pectinol, and as soon as the reaction is complete, indicated by sedimentation of precipitated pectic matter, it is filtered. Any type of filter constructed of impervious metal may be used, and the filtering material may be washable cotton pulp, diatomaceous earth or prepared discs of asbestos or paper. Extreme brilliance should not be aimed at, as too much filtration tends to reduce flavour ; good clarity is all that is necessary.

" ' The pure or slightly diluted juice is extremely acid and strongly flavoured. To make a palatable beverage it should be diluted with water and sweetened, this being done either immediately following filtration or later, according to the following directions :

" ' *Method A*. Flash heat the filtered juice into carboys at a temperature of not less than 180° F. and not more than 185° F., filling the bottles as full as possible and sealing at once. The juice so treated may then be held in storage and ameliorated and bottled or canned when required and as given under Method B.

" ' *Method B*. To the juice add an equal volume of 30° B. sugar syrup. Flash heat into bottles at 180° to 185° F., filling the bottles as full as possible and sealing at once. Stack the filled bottles so that they will cool reasonably quickly. If cans are used the double enamelled type L, Charcoal plate type is recommended. The cans are filled full, the covers immediately applied, the filled cans being then inverted and allowed to stand for 3 or 4 minutes before cooling in cold water.

" ' In Canada, juice to which sugar and water are added may not be labelled as pure ; it may, however, be labelled as juice " with added sugar and water " or as a cocktail with no ingredient declaration.

" ' Blackcurrants should yield not less than 2 tons of fruit per acre and the average yield obtained at this laboratory is 160 gallons of juice per ton of fruit. Since one gallon of juice makes 2 gallons of cocktail, an acre should yield not less than 640 gallons, at which rate the growing of blackcurrants for juice purposes should be a profitable undertaking.' "

CHAPTER III

PRODUCTION OF CANNED TOMATO, APPLE AND GRAPE JUICES IN CANADA AND U.S.A.*

By

F. E. Atkinson and C. C. Strachan

Commercial production of juices in Canada has been mainly limited to tomato, apple and grape. Smaller scale production of juices of several of the vegetables, such as celery, beet and carrot, and some of the berries such as raspberry and loganberry has been commenced. Experiments have been conducted with the manufacture of other juices such as cherry, and a combination of berry juices with apple. Nectars have also been made from apricot, peach and prune. In the manufacture of juices it has been the intention to preserve as much as possible of the flavour, colour and nutritive value of the original product from which the juice is made, for these juices are intended as food to balance the diet, and not as a replacement or substitute for alcoholic beverages.

In this Chapter, attention will be confined solely to tomato, apple and grape juices; whilst the techniques described are those in widespread use in Canada, they do embrace the latest American procedures and can thus be regarded as the most up-to-date processes in actual commercial operation.

TOMATO JUICE

The commercial production of tomato juice in Canada for the years 1940 to 1946 inclusive is as follows:

TABLE 1

CANNED TOMATO JUICE

Year	Gallons
1940	4,520,916
1941	7,616,052
1942	6,124,524
1943	5,688,036
1944	10,245,660
1945	7,240,221
1946	12,786,525

This production of juice is from standard varieties grown for canning or the fresh market.

In the production of tomato juice every effort is made to develop a juice with a colour as bright red as possible, with the natural flavour of tomatoes, and with as high an ascorbic acid content as the fresh fruit and processing will permit. It should have a consistency that is neither too thick nor too thin. The fruit should be well washed so as to remove any soil particles and trimmed to remove rots or decaying portions. Immediately after trimming it is milled, preheated, extracted, reheated, filled into cans, capped, cooked and quickly cooled (Some manufacturers now leave out the final cook. In United States areas where *Bacillus thermoacidurans* is prevalent, a " high temperature-short time " process is finding favour with processors.)

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* Forming part of Publ. 813 or Tech. Bull. 68 of the Department of Agriculture of Canada.

Grades of tomato juice in Canada

The following extract from the Meat and Canned Foods Act covers grading requirements for tomato juice.

(a) " Tomato Juice " should be packed from the unconcentrated, pasteurized liquid of the tomato with a proportion of the pulp expressed, with or without the application of heat and by any method which does not add water thereto, from whole, ripe tomatoes from which all stems and objectionable portions have been removed.

(b) If salt or sugar be used, it must be used dry or dissolved in the juice that comes from the tomatoes. Brine made from water and sugar or salt, or both, is prohibited.

(c) " Fancy Quality Tomato Juice " should have the flavour of well ripened tomatoes, possess good consistency and be free from particles of skin, seeds, and minute pieces of core ; the colour of this grade should be equal to or better than the colour designated " Dull Terra Cotta " (No. 4) plate 331, Répertoire de Couleurs, except that it must be somewhat more pink; or that produced by spinning a combination of the following Munsell colour discs—70 per cent. (5R 2.6/13—glossy finish) ; 15 per cent. (2.5YR 5/12—glossy finish) ; 5 per cent. (N1—glossy finish) ; 10 per cent. (N4—matte finish).

(d) " Choice Quality Tomato Juice " should have the flavour of well ripened tomatoes, fairly good consistency and be practically free from particles of skin, seeds and minute pieces of core ; the colour for this grade should be equal to or better than the same tone as, but slightly less orange than, the colour designated " Dull Terra Cotta " (No. 4) plate 331, Répertoire de Couleurs ; or that produced by spinning a combination of the following Munsell colour discs—67 per cent. (5R 2.6/13—glossy finish) ; 20 per cent. (2.5YR 5/12—glossy finish) ; 4 per cent. (N1—glossy finish) ; 9 per cent. (N4—matte finish).

(e) All containers of tomato juice shall be coded daily.

In tomato juice, mould filaments shall not appear in more than 25 per cent. of the microscopic field ; bacteria shall not exceed fifty million per cubic centimetre ; yeasts and spores shall not exceed 65 per 1/60 cubic millimetre.

The copper content of tomato products shall not exceed 50 parts per million of dried total solids.

The canning of tomato juice

To obtain the desirable qualities in a tomato juice, a line as depicted in Fig. 22 may be employed. The various items in this line are indicated by numbers from 1 to 24. Fig. 22 (1) indicates a half-round, steel trough of a minimum of 50 feet in length and 14 inches in diameter. Some troughs have been built 90 feet long and 20 inches in diameter. This water conveyor need not be in a straight line and can be used to convey tomatoes from the receiving platform to the remainder of the line. The important object of this part of the system is to loosen the adhering dirt, especially the clay that is characteristic of some tomato-growing areas. The flume is particularly adapted to this purpose as the tomatoes receive considerable agitation as they pass down it to the soaker tank (Fig. 22 (4)). Only sufficient gradient is put on the flume to drain it dry after cleaning, for example 2 inches in 50 feet. This flume is sometimes replaced by an additional soaker tank.

As the tomatoes emerge from the flume they pass over a slatted grill above a tank, Fig. 22 (3), where the water from the flume is recirculated by a pump, Fig. 22 (2). A baffle placed in tank (3) to guide the water containing the soil from the tomatoes to the side of the tank opposite the pump inlet is recommended. The tomatoes pass through and fall into soaker tank (4). This is a roller table, soak tank and washer. There should be a continual overflow from tank (3) so that the water is maintained reasonably clean. In soaker tank (4), the tomatoes fall into the deep end of the tank and are conveyed upwards and forwards by means of a roller belt. At the higher end of the belt where it is still covered but out of the water, sprays of fresh water give the tomatoes additional cleansing. From the soaker tank belt the tomatoes fall into a rotary washer (5), where they are agitated and exposed to sprays of water under high pressure (approximately 125 p.s.i.). The quantity and pressure of water should be so adjusted that the soft tomatoes will become completely disintegrated and be washed down

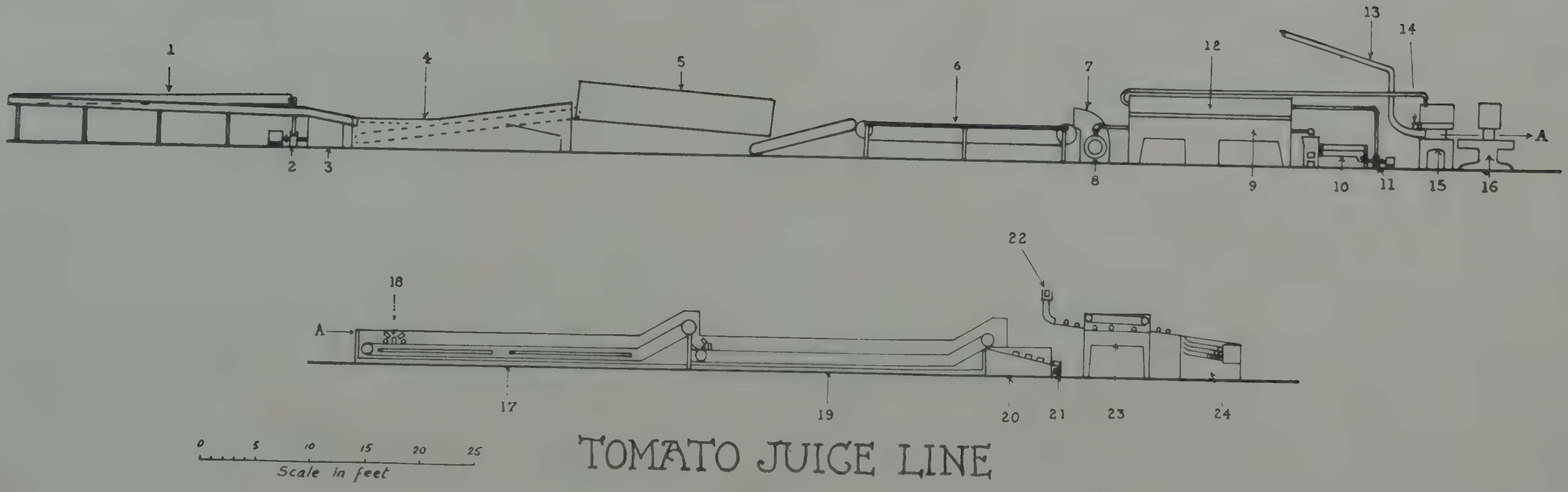

FIG. 22.
Continuous tomato juice line.

the drain at this point. This machine may be eliminated if no trouble is encountered in keeping the pack within the government mould count tolerance.

Firm, wholesome tomatoes continue through this washer and up an elevator on to an inspection roller belt, Fig. 22 (6). Here cracks or other defects are removed as the tomatoes are rolled over as they pass before the trimmers. The length of roller belt often used is relatively short—about 20 feet. With this length of belt one of two things is necessary, either a very high quality tomato or some method of rapid trimming. One company has solved this problem by placing an endless pintle link chain made in stainless steel above the rubber belt. This chain has diamond-shaped attachments 5 inches wide riveted to the links. Normally this chain is operated with the diamonds in a horizontal position and is used for conveying the fruit. However, in this adaptation, instead of the diamond being flat or in a horizontal position, it is placed vertically and each upward diamond point is used to impale tomatoes that require trimming. The women operators always place the part of the tomato to be trimmed on the same side of the diamond link. As the chain progresses it eventually passes under a sharp knife on the same side of the belt as the portion of tomato that is to be trimmed. When the operators merely have to impale the tomatoes and not actually perform the trimming, the operation is accelerated.

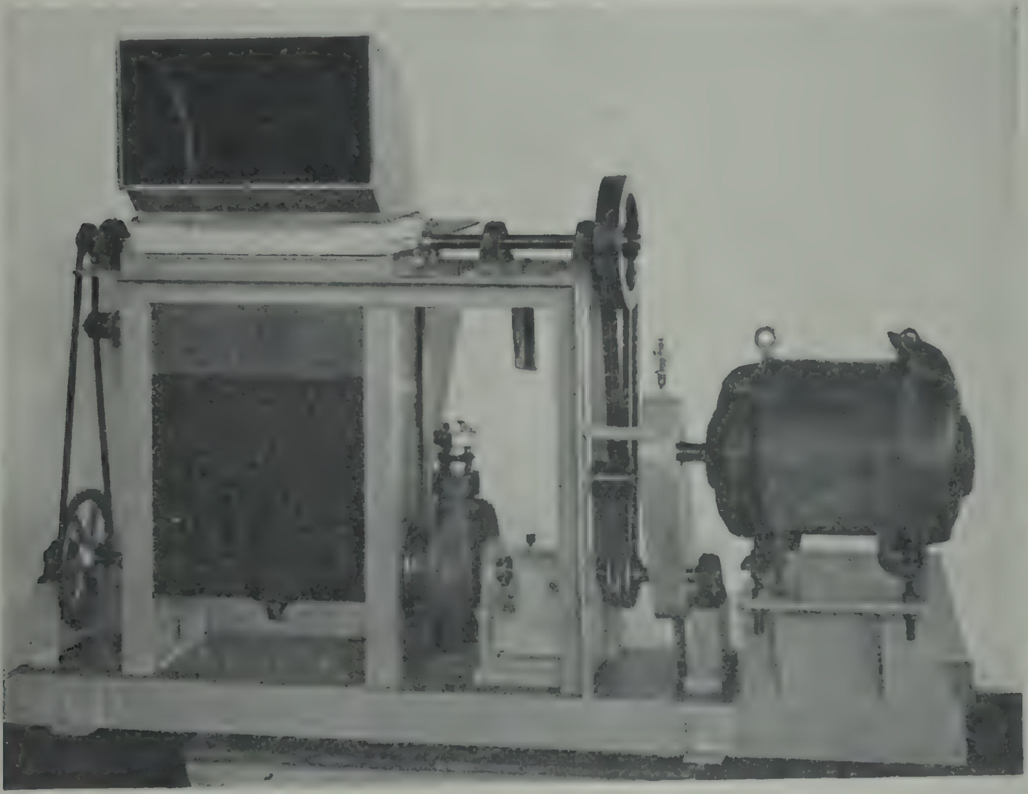

Fig. 23.

Tomato mill.

From the trimming belt, the tomatoes fall into a tomato mill, Fig. 22 (7) and Fig. 23, and are ground sufficiently fine so that they may be passed through a nickel alloy pump (8) and through a preheater, Fig. 22 (9) and Fig. 24. Considerable significance is attached to this part of the process. After the tomatoes have been milled the sooner they can be heated to a temperature of at least 190° F., the more ascorbic acid will be retained if the remainder of the process is properly handled. The time from the milling of the tomato until it is preheated to 190° F. or higher should only be a few seconds.

The heated, milled tomatoes then pass from the preheater into the tomato juice extractor, Fig. 22 (10) and Fig. 25. This machine is of stainless steel or other nickel alloy, and is of the expeller-extractor type. The screen perforations are usually 0·020 inch and there is an adjustable clearance at the end of the screen so that the desired pressure can be readily obtained. The usual setting at this point is for a yield of 65 to 70 per cent. of the tomatoes as juice. A second nickel alloy pump, Fig. 22 (11) takes the juice from the extractor and passes it through the pasteurizer (12) to heat it again to 190°-195° F. for filling.

The filling operation takes place at Fig. 22 (15), and Fig. 26—this machine (Fig. 26) being supplied with clean cans from the can track, Fig. 22 (13). A can washer on the empty can supply line is not shown in Fig. 22, but is illustrated in Fig. 27. Before these cans are filled, a salt tablet is deposited by an automatic salt dispenser, Fig. 22 (14). Some firms have adopted the policy of using two salt tablet dispensers, each putting in a tablet of half the usual size. By this method, if one machine is out of operation each can will always get half a tablet.

From the filling machine the cans pass through the closing machine, Fig. 22 (16). The filling machine, Fig. 22 (15), will probably be set to handle 125 to 225 cans per minute. The can transfer between filler and capper must be sufficiently smooth that undue spillage is avoided. Fig. 26 illustrates a satisfactory set-up. Experiments have shown that the loss in ascorbic acid content in tomato juice in the can is proportional to the headspace (2). In other words, the loss in ascorbic acid is proportional to the oxygen contained in the headspace (4, 12). Consequently it is desirable to close the cans while they are still as full as possible.

From the closing machine, the cans roll into a track that conveys them into a cooker, Fig. 22 (17). Here the cans receive a cook of about 10 minutes at 208° F. and then are cooled in a draper belt cooler, Fig. 22 (19). Draper belt cookers and coolers have been indicated as they are in common use and are often built by the canning factories themselves. However, there are very efficient rotary cookers and coolers on the market that may be installed if they are available and if the processor can afford the extra cost. With the rotary machines the cans progress on a spiral through the machine and thus do not require unscrambling. With the draper belt cooker and cooler an unscrambler, Fig. 22 (20), and Fig. 28, is necessary.

When the " high temperature-short time " process is used, the juice is heated in a heat exchanger to 250° F. for 42 seconds and rapidly cooled to 190°-200° F. before filling. The cans are sealed, held 3 minutes and rapidly cooled.

After the cans fall out of the end of the unscrambler they are fed on to a belt, Fig. 22 (21), which elevates them usually to the ceiling of the warehouse. They are righted by passing through a can twister and travel on a can track for several hundred feet so that their outside surfaces are dry when they pass through the labelling machine, Fig. 22 (23) and Fig. 29. After the cans pass through the labeller, they roll into a casing machine, Fig. 22 (24) and Fig. 30, and are cased. Large operators are using stitchers, case gluers and sealers. If this machine is used, the cases are merely formed and placed on the casing machine. When the case is filled it is placed on the gluer, sealer and former. From this machine the cases are placed on pallets and stored in the warehouse ready for shipment. If the cans are not labelled immediately, the labeller is omitted and the cans passed directly from the drying track into the casing machine and are cased bright.

This line permits a high speed operation with a minimum of supervision. However, it must be pointed out that there are plants making satisfactory products in which the juice, previously extracted at 190° F., is accumulated in 100 gallon tanks. In these tanks it is salted, heated and delivered to the filling machine. In this case, the juice is in the tank for a few minutes only. Experiments have shown that no significant loss in quality or vitamin content occurs if the holding period does not exceed 10 minutes. It has also been shown that where tomato juice is manufactured under proper conditions not more than 2 to 3 mg. ascorbic acid per 100 ml. of juice should be lost from the content in the original tomato material in the manufacturing process. This retention has been possible only when small holding tanks are available.

There is some correlation between the retention of ascorbic acid and quality (6, 13). The equipment and the processing technique have a definite influence on the ascorbic acid content of the final product (see page 114). Consequently an effort is being made to include an ascorbic acid assay as a factor in grading commercially canned tomato juice.

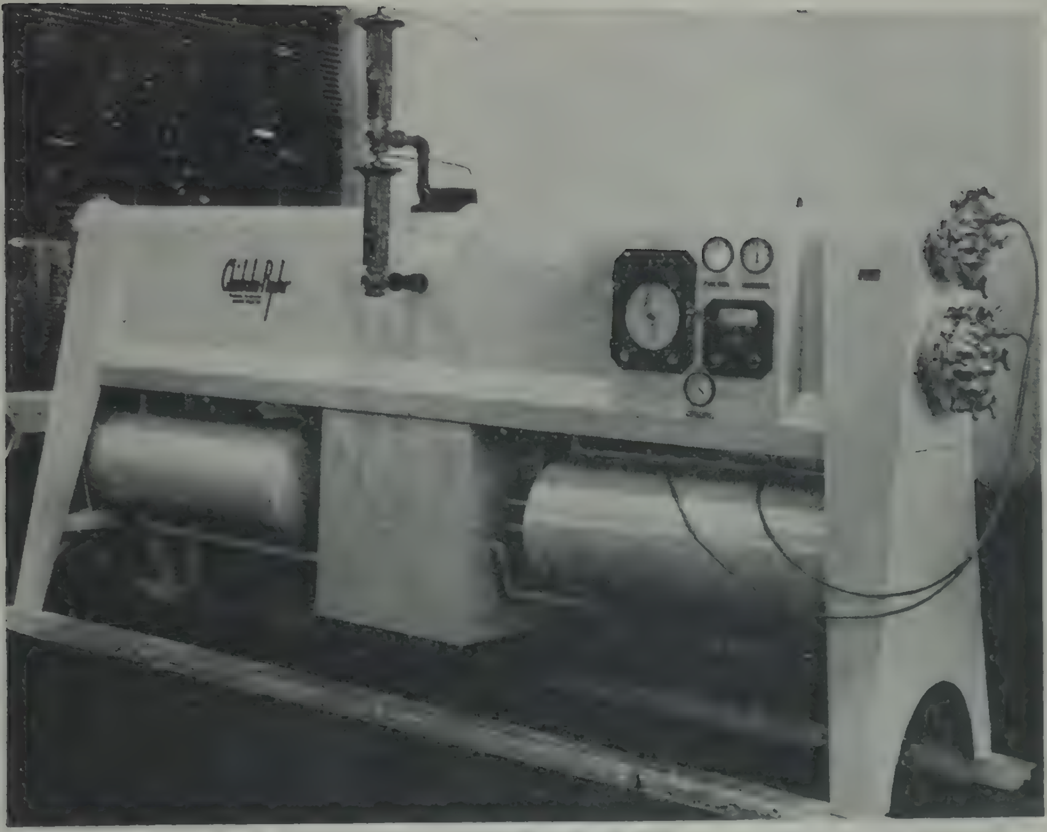

FIG. 24.
Combined preheater and pasteurizer.

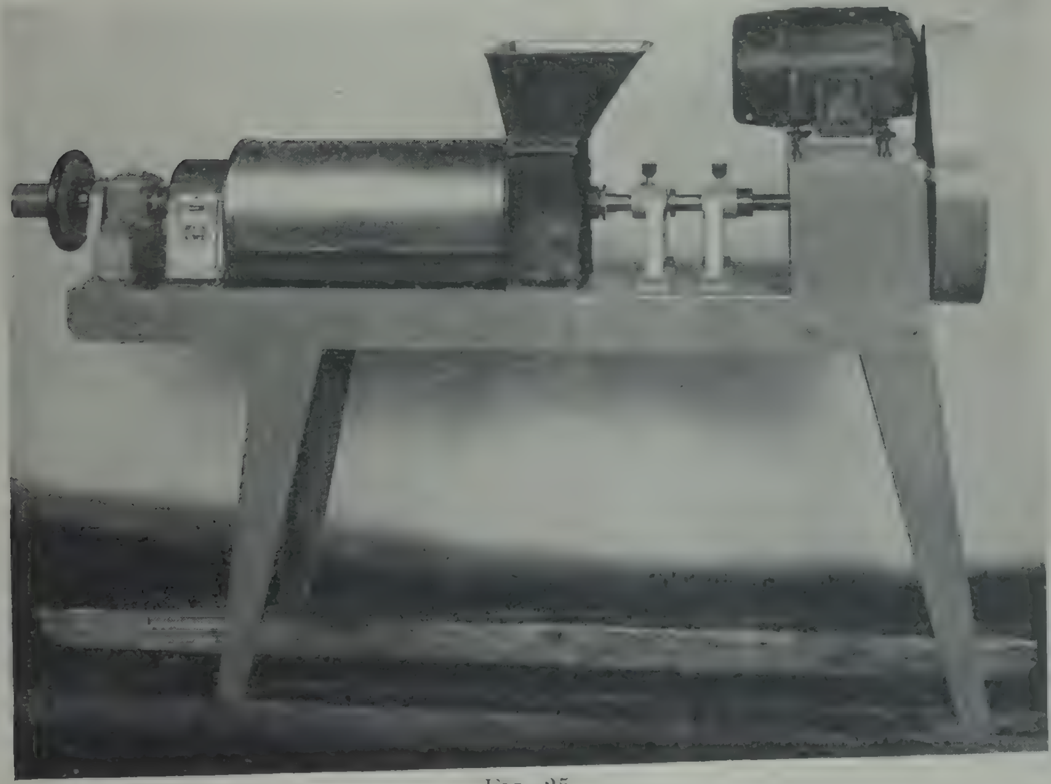

FIG. 25.
Tomato juice extractor.

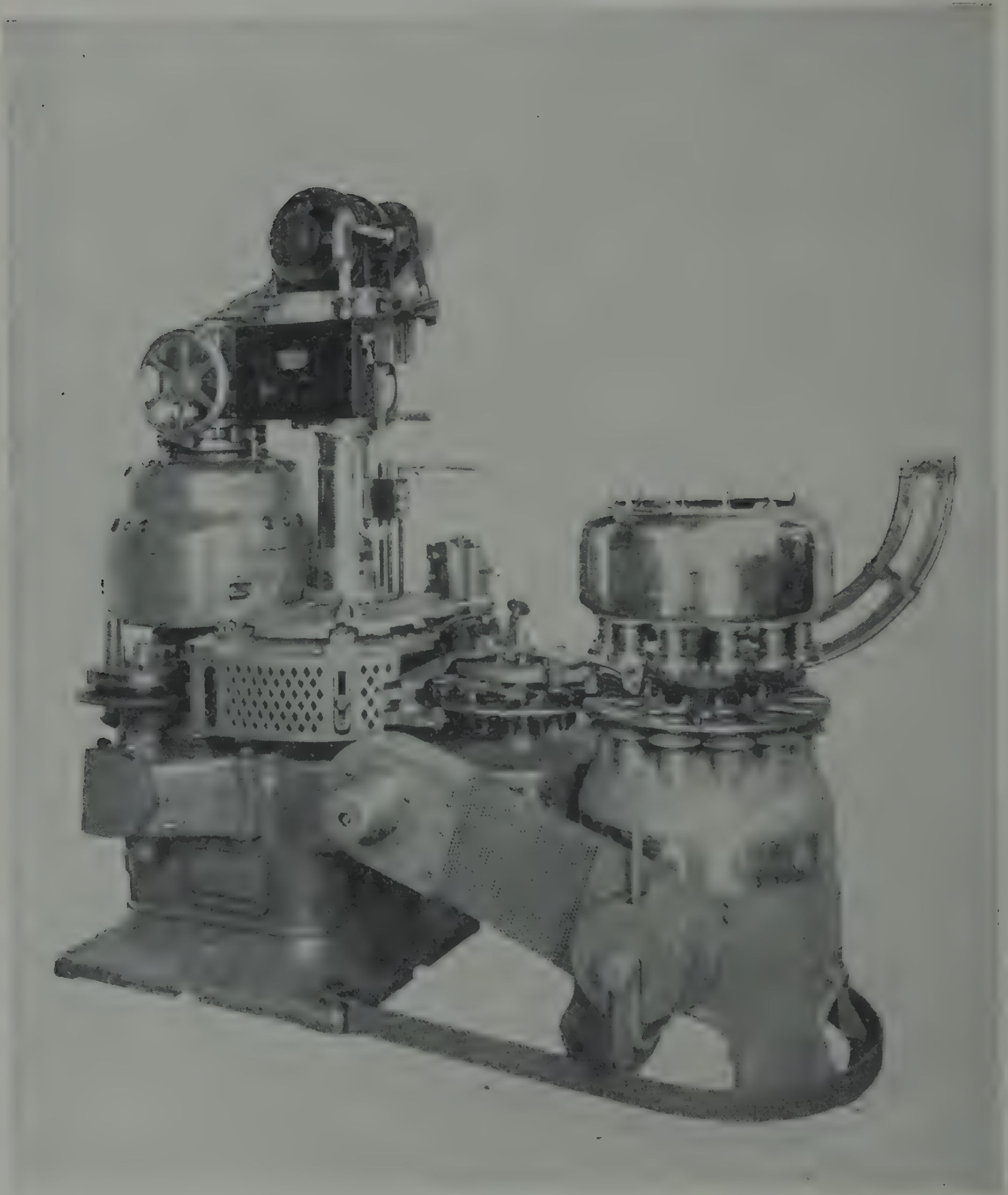

FIG. 26.

Rear view of a close hook-up of high speed capper and 12-valve filler.

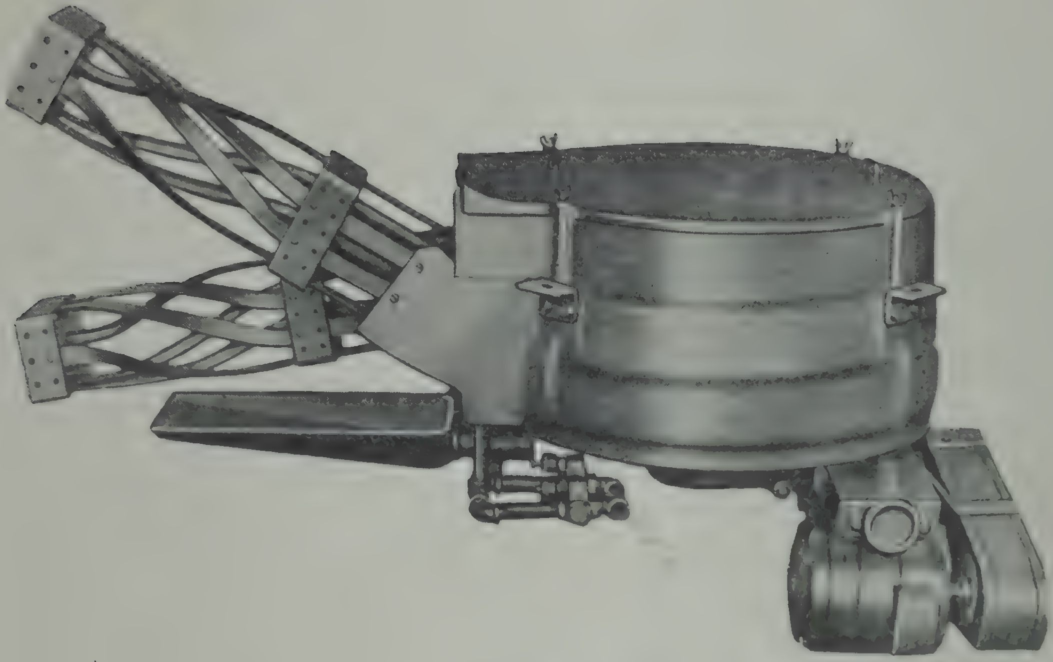

FIG. 27.
Empty can washer.

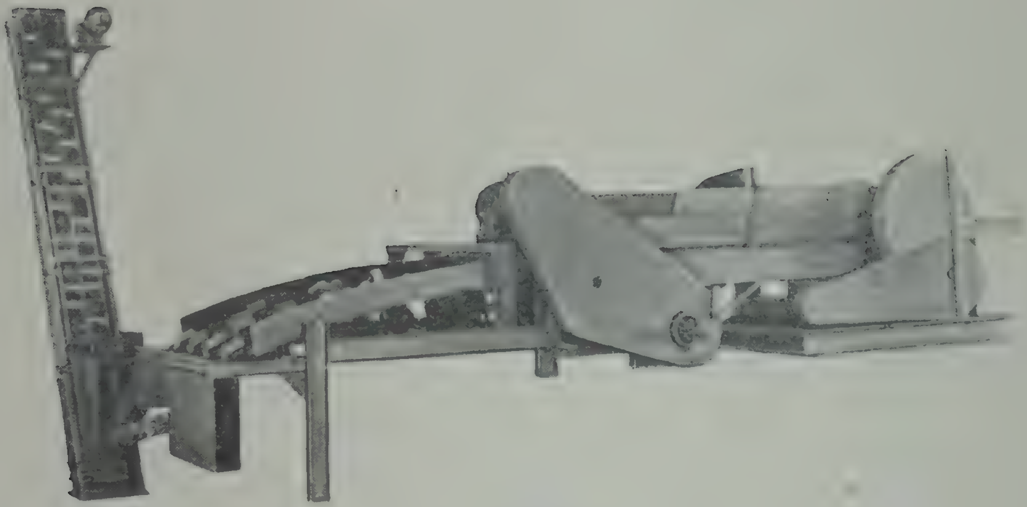

FIG. 28.
Can unscrambler.

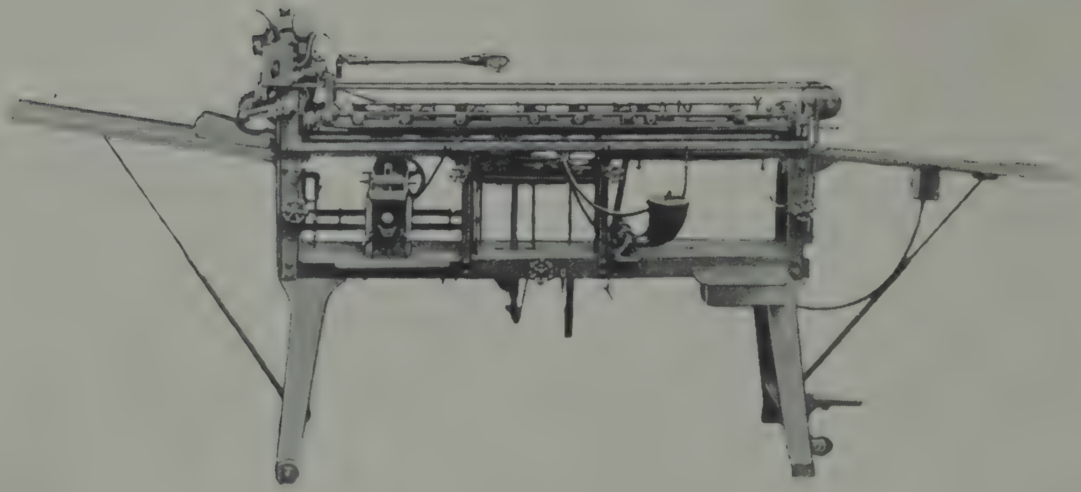

FIG. 29.

Labelling machine.

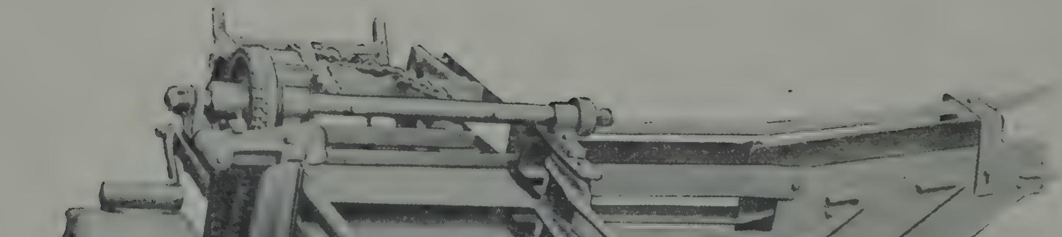

FIG. 30.

Casing machine.

Equipment for canning tomato juice

Three points may be considered under this heading. Firstly, the equipment should be capable of being cleaned easily. Secondly, it should be of a type that allows continuous operation so that as much as possible of the nutritive value of the tomato can be retained. Thirdly, it should be economical to operate.

As all tomato juice produced in Canada for inter-provincial shipment is required to pass minimum mould count requirements, the design of equipment to provide for easy cleansing is very important. All the items indicated in Fig. 22 by the numbers 1, 2, 3, 4 and 5 are for washing the tomatoes. No. 5, which is a rotary washer, can be especially effective if water under a sufficiently high pressure is used to remove the soft decaying tomatoes. The roller trimming belt is 24 inches wide and 20 feet long. The rollers may be made of any of the resistant white metals such as stainless steel or aluminium. Whatever the material, it should be built on a stand so that it can be thoroughly cleaned between shifts.

The preheater, Fig. 22 (9), should be fitted with stainless steel or nickel tubes. The milled tomatoes or extracted tomato juice pass through these tubes. Care should be taken to see that the tubes are always bright and do not become encrusted with tomato solids. This piece of equipment in particular should be built so that it can be quickly and thoroughly cleaned. It is automatically controlled to obtain the desired temperature. The reheater, Fig. 22 (12), forms the top part of the preheater and the remarks on construction and cleanliness of the preheater apply equally.

Another feature that aids in standardizing the sterilizing process is the location of a bulb of an automatic temperature control in the bowl of the filler. If the temperature drops too low the whole line is shut off by this control.

In the foregoing pages a continuous line has been described that has been in common use in U.S.A. and Canada. It is thought that the inclusion of a cook with this process is valuable insurance. The high temperature-short time process may become necessary in Canada if *Bacillus thermoacidurans* becomes well established in tomato districts. If ascorbic acid retention does eventually become a grading factor, equipment will have to be installed that will ensure the maximum retention.

APPLE JUICE

Most of the commercial apple juice packed in Canada has been the clarified fresh product, sterilized with a flash pasteurizer and filled hot into enamel-lined cans which are then closed and cooled. During the war years it was mandatory that the clarified juice be fortified with ascorbic acid so that a minimum of 35 mg. per 100 ml. would remain in the juice whenever it was tested up to 12 months after packing.

The crushed type of apple juice has also been packed in British Columbia. In this juice an effort has been made to preserve the natural colour and flavour of apple flesh, and part of the pulp is included so that the final product has from 3 to 10 per cent. of suspended or finely ground solids.

Experimental work has been concluded at the Summerland Fruit and Vegetable Products Laboratory on a type of apple juice which is midway between the crushed and the clarified modifications. In this juice, ascorbic acid is sprayed on the apples as they enter the hammer mill. The amount of ascorbic acid used is sufficient to prevent darkening of the juice for at least half an hour. The pulp from the hammer mill is then pressed in a conventional hydraulic rack and cloth press and the juice obtained is passed through a de-aerator prior to pasteurization into cans.

The Canadian production figures of canned apple juice from 1940 to 1946 are given in Table 2.

Varieties of apples for juice

Most of the autumn and winter varieties are suitable for canned apple juice, that is, either by themselves or as a blend. In British Columbia the juice season starts with McIntosh and as this crop constitutes about one-third of the production, it is natural that a high proportion

TABLE 2

CANNED APPLE JUICE

Year	Gallons
1940	1,221,579
1941	1,217,007
1942	557,931
1943	674,853
1944	1,203,858
1945	462,321
1946	1,897,464

of the juice is of this variety alone. If the McIntosh apples used are well coloured and at an optimum eating-ripe maturity, the quality of the juice is quite good. On the other hand, poorly coloured apples have less flavour and sugar. Also juice from any over-ripe McIntosh lacks flavour and is extremely mild.

Jonathans also have been found to be very desirable for juice as well as winter varieties such as Winesap, Stayman and Newtown. Delicious constitutes the one commercial variety which is not considered suitable for juice by itself. The resulting juice is too sweet and not sufficiently sprightly. Fifteen to 20 per cent. of this variety can be blended with a variety such as Newtown or Winesap to give a juice of high quality. An attractive commercial juice has been made by blending lime juice with Delicious apple juice. Also Hyslop crab apples have been used to make up the acid deficiency in Delicious juice. In this case, 25 per cent. of crab apples and 75 per cent. of Delicious gave a satisfactory product. Constituents of several varieties of apples grown commercially in British Columbia, analysed at their optimum state of ripeness for juice manufacture, are given in Table 3.

In Eastern Canada, Arengo-Jones (1) states " it has been found that the juice of well ripened McIntosh will supply desirable flavour, and when blended with lightly flavoured juice such as Stark, Spy or Ben Davis, only about 25 per cent. is required."

The juice should not be too sweet or too heavy in body. Astringency is of less importance than the correct sugar-acid balance, though it should not be above 0·1 per cent.

The following is a list of apples and blends that have been used at Ottawa :

Ribston : If pressed when fully ripe, Ribston makes a good juice. The flavour is not strong but very fruity. It may be blended with Wealthy, King or Greening.

Stark : The juice from this apple does not carry much flavour, but being neutral in flavour and low in acidity it blends well with early picked McIntosh and Baldwin. Some very good juice has been made with Stark alone when the acidity was above 0·5 per cent.

Baldwin : This juice carries a rich flavour when the fruit is ripe. The acidity varies considerably, but at an acidity of not over 0·55 per cent. the juice is good without blending. During December, about 10 per cent. McIntosh should be added. After December the juice is very liable to be " musty " due to the apples moulding at the core.

Spy : Until ripe this apple yields a juice which is generally quite acid and without much flavour. It blends very well with McIntosh using about 25 per cent. of the latter. When ripe, no blending is required.

Golden Russet : This apple is very popular in the United States where the heaviness of the juice is appreciated. For a rich, aromatically flavoured juice it may be blended in equal volumes with Spy or the addition of a little McIntosh juice will provide more apple flavour.

McIntosh : The juice of this apple grown in Ontario and Quebec is extremely valuable for blending and the flavour is very stable in the bottled product. Used alone, the flavour is sometimes too strong and it ages to almost a "perfumed" flavour. It may be blended with any of the winter varieties, 25 per cent. being the maximum amount necessary. Until the acidity drops below 0·45 per cent., McIntosh may be used alone.

Melba : The juice of this variety when in prime " eating-ripe " condition makes an excellent grade of juice and is highly recommended.

TABLE 3

COMPOSITION OF APPLES GROWN IN BRITISH COLUMBIA (1943-45) AND ANALYSED AT OPTIMUM RIPENESS FOR JUICE MANUFACTURE

Variety	Constituents per cent. by weight						
	Soluble solids*	pH	Total acid (malic)	Sugar as invert			Tannin†
				Total	Reducing	Sucrose	
licious							
Average	13·16	3·91	0·27	11·79	8·81	2·89	0·0261
Maximum	13·90	4·08	0·58	12·65	10·13	3·52	0·0329
Minimum	12·31	3·78	0·20	10·92	8·28	2·10	0·0212
No. of samples ..	14	11	19	19	10	10	5
lden Delicious							
Average	14·26	3·60	0·41	12·39	7·86	3·78	0·0275
Maximum	15·74	3·72	0·51	13·31	7·97	5·34	0·0364
Minimum	13·20	3·48	0·32	11·60	7·75	2·21	0·0235
No. of samples ..	4	4	4	4	2	2	3
nathan							
Average	13·56	3·33	0·64	11·45	8·29	2·97	0·0233
Maximum	14·87	3·40	0·74	12·33	8·91	3·49	0·0329
Minimum	11·91	3·27	0·48	10·46	7·97	2·36	0·0134
No. of samples ..	7	9	9	9	7	7	5
bilee							
Average	14·94	3·53	0·40	12·60	8·02	3·90	0·0341
Maximum	17·22	3·64	0·49	14·02	8·26	3·90	—
Minimum	13·20	3·41	0·34	11·57	7·78	3·89	—
No. of samples ..	3	3	3	3	2	2	
cIntosh							
Average	12·72	3·35	0·54	10·89	8·30	2·61	0·0375
Maximum	15·59	3·51	0·74	13·17	10·15	3·61	0·0625
Minimum	11·82	3·18	0·33	9·60	7·22	1·47	0·0138
No. of samples ..	10	22	22	22	16	16	7
ewtown							
Average	13·76	3·31	0·61	11·67	7·50	4·18	0·0169
Maximum	14·24	3·46	0·68	11·99	7·82	4·37	—
Minimum	12·82	3·15	0·50	11·46	7·09	3·88	—
No. of samples ..	5	5	5	5	4	4	—
ayman							
Average	13·81	3·37	0·59	11·69	7·05	5·02	0·0236
Maximum	14·34	3·42	0·62	12·07	—	—	—
Minimum	12·94	3·30	0·52	11·17	—	—	—
No. of samples ..	3	3	3	3	1	1	—
inesap	14·83	3·47	0·58	12·82	10·67	3·14	0·0271
ealthy	11·90	3·10	0·84	9·85	8·06	1·72	0·0230

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* By refractometer.

† Determined by method of Hartman, B. G. *J. Ass. off. agric. Chem.*, **26** : 452-62, 1943.

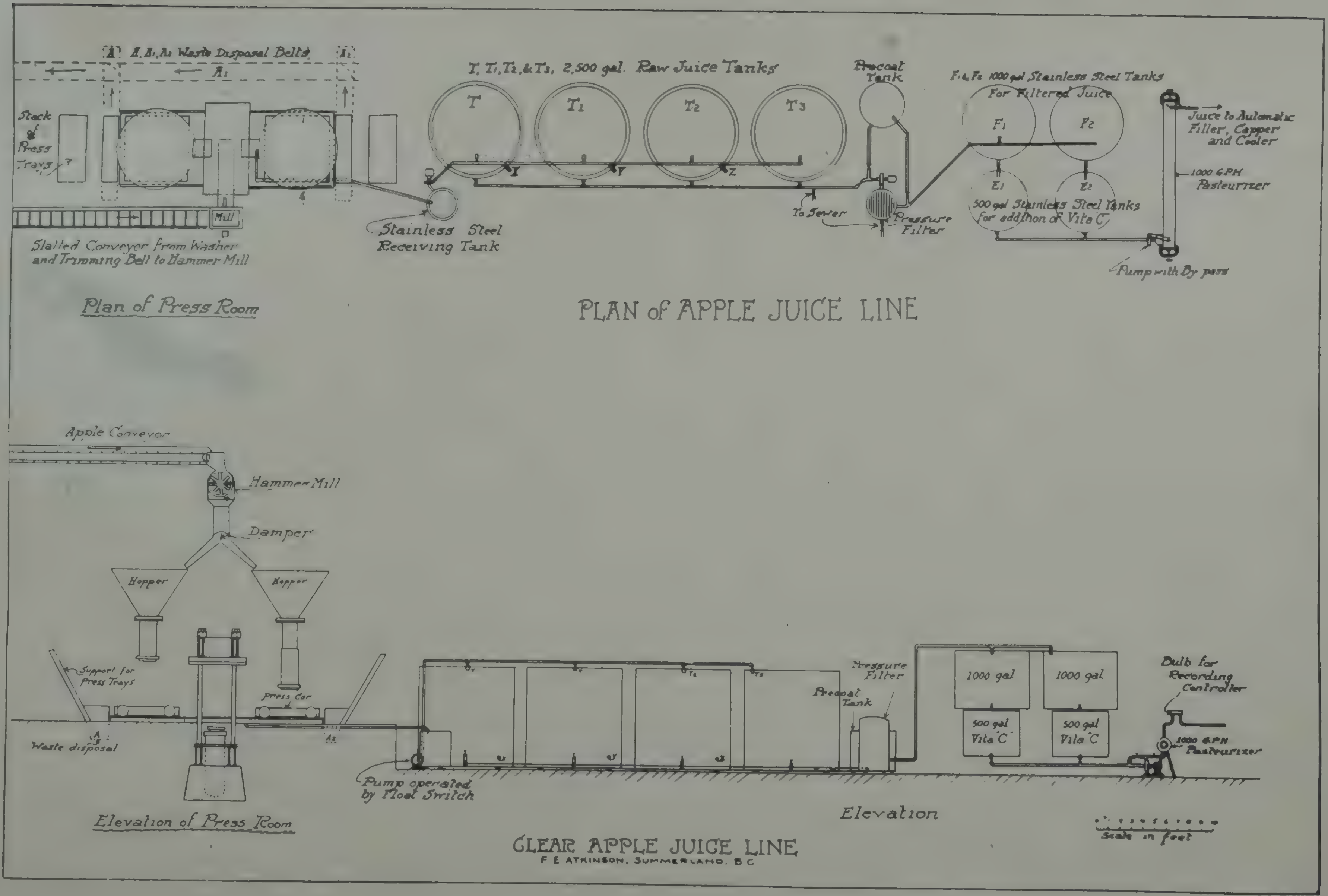

FIG. 31.
Floor plan and elevation of clear apple juice line.

Wealthy: Requires blending with McIntosh.

Snow: Blends well with McIntosh.

Marshall (7) reported that for Michigan a typical blend of some of the juices having the best quality would be: Northern Spy, 20 to 40 per cent.; Grimes Golden, 10 to 20 per cent.; Baldwin, 10 to 30 per cent.; and 10 to 20 per cent. of one or more of such varieties as Stayman, McIntosh, Delicious, or Rhode Island Greening. He also considered that Jonathan may be blended with three or four of the other important commercial varieties. His observations indicate that any of four or five commercial varieties that are available in a fully ripened condition after early October may be used to make a satisfactory blend of juice.

Regardless of the variety, the apples used in juice should be in a prime eating condition and although they may be culls due to insect injury or blemishes, they should be of a quality that has the flavour of the variety well developed.

Grades of Canadian apple juice

"Choice quality apple juice" must have a specific gravity of not less than 1·045 when tested by hydrometer and an acidity of not less than 0·4 and not more than 0·65 per cent. malic acid by volume. Juices with a higher acid content are marked "sharp" or "acid" type. The specifications for "Fancy quality apple juice" are similar except that the juice must have a specific gravity of not less than 1·050.

The canning of apple juice

(*a*) *Clarified juice*

In Fig. 31 a floor plan and elevation of a clear apple juice line is depicted. The starting point at the washer and trimming belt is not shown. However, the washer should be of a type in which 1 per cent. hydrochloric acid can be flooded over the fruit at a temperature approximating to 130° F. This wash may slightly crack the skins, but as the apples are to be ground shortly after they leave the washer, this injury is unimportant. The acid wash is followed by a cold fresh-water wash. After washing, the apples pass over a trimming belt where defects are cut away.

The line commences with a slatted conveyor delivering apples to a hammer mill (Fig. 32). This mill is a fixed hammer type made of stainless steel. Various sized screens may be used, depending on the firmness of the apples. (Rietz disintegrators, Fig. 33, are being successfully used in some American factories.) From the mill the pulp falls through shutes to one of two hoppers. In these hoppers the pulp accumulates and is fed on to press cloths on trolleys from the telescopic shute at the bottom of the hopper.

The press room arrangement suggested in Fig. 31 is called the "in and out" arrangement. Each trolley moves from under the loading shute on to the hydraulic press and is pressed and then moved back under the loading shute. While one trolley of cheeses is being pressed, the other is unloaded and reloaded. As the press cloths are removed from the racks they are shaken over the waste disposal belts shown as A and A2. The press racks are leaned against the supports for this equipment while additional supports may be provided for

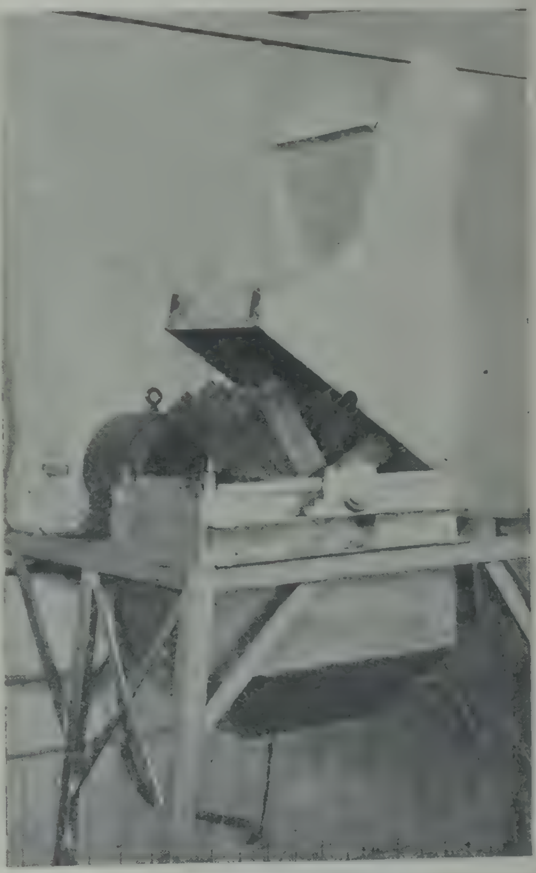

FIG. 32.

Stainless steel hammer mill with housing opened to show fixed hammers.

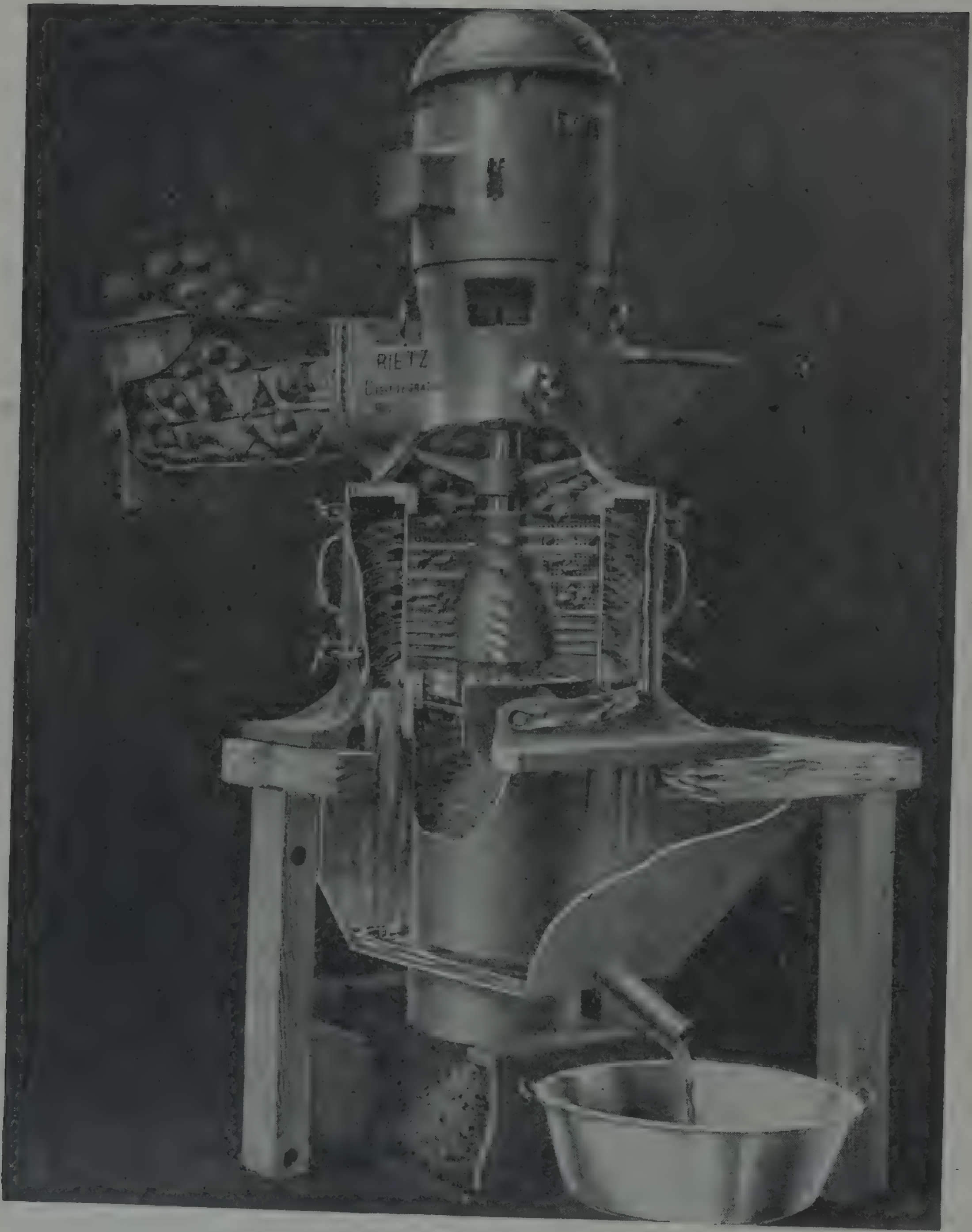

FIG. 33.
Cut-away photograph of Rietz disintegrator.

the press cloths. The waste carried by belts A and A2 is deposited on belt A1 and may be taken to a hopper outside the building, from whence it may be hauled by trucks or used in other processes (i.e. dried).

The juice obtained by pressing flows through a stainless steel pipe to a receiving tank. This tank is equipped with a float-operated switch to start and stop the pump motor. This pump delivers the juice to tanks shown as T, T1 and T2. Each of these tanks has a capacity of 2,500 gallons and is equipped with a heating coil to aid in clarification. T3 is reserved for partially clarified juice, obtained either by enzyme preparations, tannin and gelatin, or a combination of the two. A suction line from a portable pump is connected to tanks at X, Y and Z, and the partially clarified juice pumped to tank T3. (Further information on the use of clarifying agents is given on pages 57, 62.)

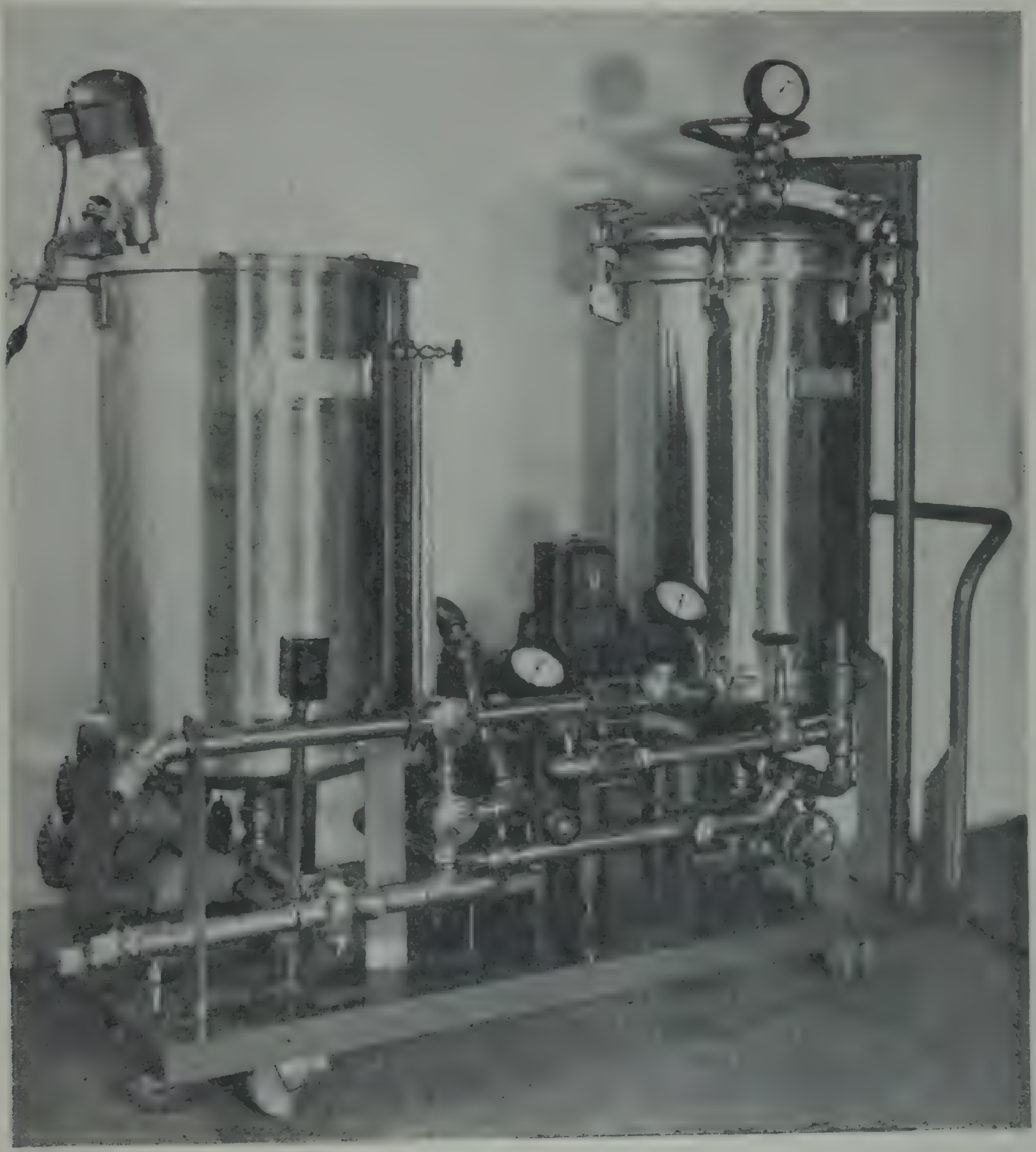

FIG. 34.

Cylindrical filter with precoat tank.

The juice from T3 is pumped through the cylindrical pressure filter, Figs. 34 and 35, and delivered to 1,000 gallon tanks (Fig. 31, F1 and F2), in which it is held before being pasteurized. If, however, the juice is to be fortified with ascorbic acid, it is run by gravity from

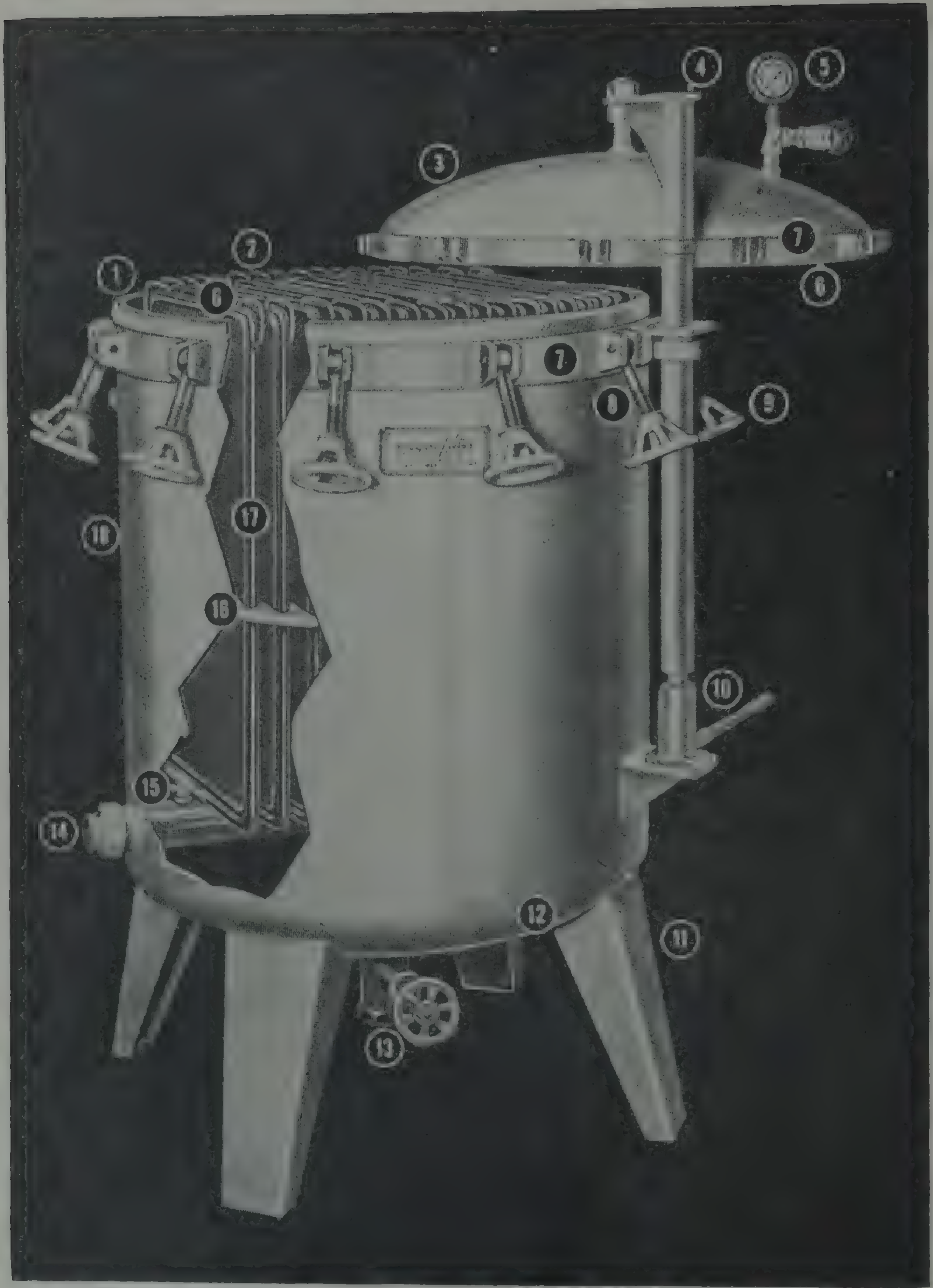

FIG. 35.

Cut-away of cylindrical pressure filter.

1. Machined cover-gasket bearing surface.
2. Leaf handles.
3. One-piece seamless dished-head cover.
4. Cover lift beam.
5. Vent gauge assembly.
6. Machined cover-gasket groove.
7. Heavy reinforcing rings.
8. Forged steel eyebolts.
9. Heavy handwheels.
10. Hydraulic cover lift.
11. Formed support legs.
12. One-piece seamless dished-head bottom.
13. Combination inlet and drain.
14. Filtrate manifold outlet.
15. Cast leaf nozzles.
16. Slotted leaf-spacer bars.
17. Tubular leaf frames.
18. Welded tank shell.

the 1,000 gallon tanks to 500 gallon tanks E1 and E2 for the addition of ascorbic acid. It has been found that in the addition of ascorbic acid the batch of juice should be of such a volume that it can be run through the pasteurizer in not more than half an hour.

The juice from either the 1,000 gallon or 500 gallon tank is pumped to a cylindrical pasteurizer (Fig. 36) and heated in about 11 seconds to 190° F. This pasteurizer was developed by the Fruit and Vegetable Products Laboratory at Summerland, B.C., and is in general use in the apple juice factories of British Columbia. There are, however, many other types of pasteurizers that are satisfactory for apple juice. The nickel alloy pump supplying the juice to the pasteurizer is equipped with a by-pass so that the temperature can be roughly adjusted by hand. An automatic control on the steam supply to the pasteurizer effects the remainder of the regulation. From the pasteurizer the juice flows to an automatic filler and from there to a capper and cooler. Originally it was suggested that a 2-minute holding period should follow the closing of the cans. However, commercial practice has been to cool immediately after capping. The can in general use for clarified juice is made of type L steel plate with a 1·5 per cent. tin coating and fruit enamel lining. As with tomato juice, a speed of 125 to 225 cans per minute requires a special transfer system between filler and capper to prevent undue spillage. Here again the same situation is true as in the case of tomato juice, i.e. the loss in ascorbic acid is proportional to the oxygen contained in the head space.

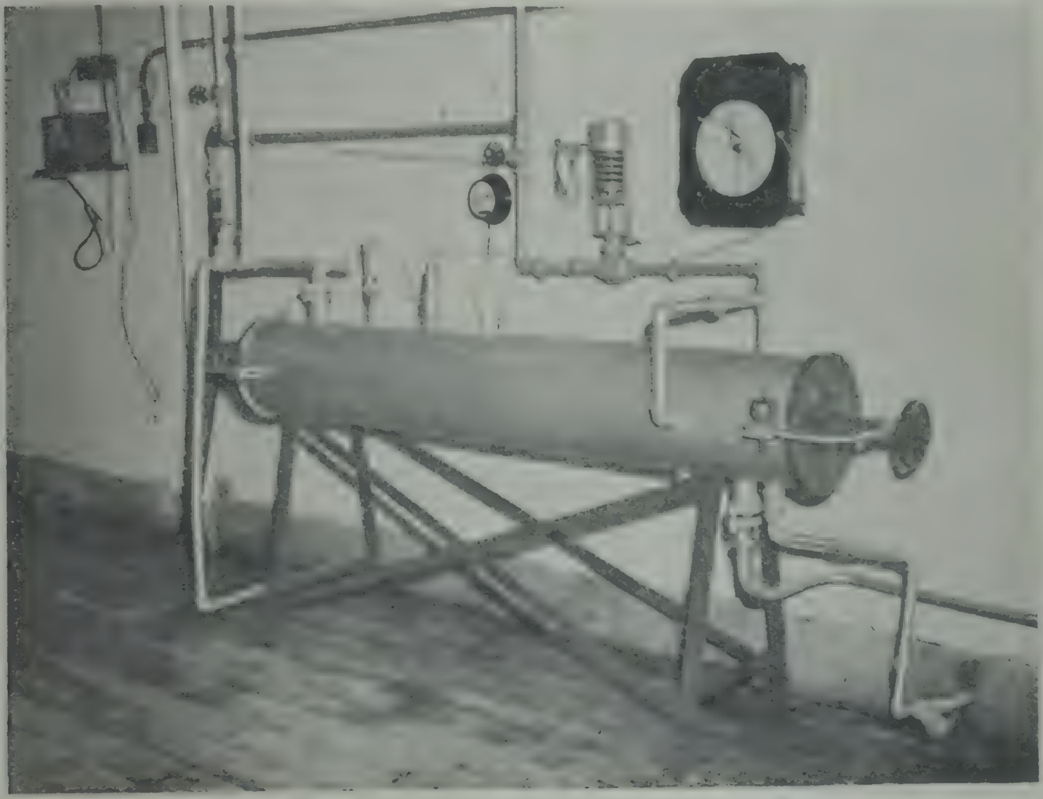

FIG. 36.
Cylindrical pasteurizer.

(b) *Crushed apple juice*

Crushed apple juice is quite different from clarified juice in that it contains fine cellular material and every endeavour is made to keep the product from oxidizing and developing grey or darker colours. It has been advertised as " liquid apple " and this in a sense is a true statement. If the juice is properly made, one can determine the variety by the aroma and flavour of the juice. The colour is also the natural colour of the apple flesh.

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In its manufacture the apples are washed and trimmed in a manner similar to that employed in the production of clarified juice, but instead of passing through a hammer mill the apples pass through a rough slicer which cuts them into thick slices. The slices then fall into a Schwarz comminutor-extractor which is the chief feature of the process.* [The machine is only rented to processors on a fixed royalty charge.] This is a vertical mill which grinds the apples and forces the fine particles and juice through special rubber screens. These screens are made of hard rubber and are perforated with holes which vary in number from 1,600 to 3,600 to the square inch. The Schwarz machine has very fine clearances and can be regulated to give the desired amount of suspended solids. The amount of solids now considered best is between 3 and 10 per cent. The juice is drawn from the extractor by a vacuum line which delivers it to the de-aerator. In this particular case a de-aerator with horizontal shallow pans has been used with a vacuum of 29·4 inches. From the de-aerator the juice is pumped with a turbine type stainless steel pump. In order to make the work of this pump as easy as possible the de-aerator is located several feet higher than the pump, which delivers the juice to a homogenizer and thence to a pasteurizer. In the pasteurizer, the juice is heated to 190° F. and delivered to an automatic filling machine. From then on the process is the same as for clarified juice. Under ideal conditions, plain cans can be used for this type of juice.

(c) *Natural apple juice*

In clarified juice oxidation occurs, leading to a brown or amber colour, and a characteristic flavour develops which is not the flavour of the fresh apple. Furthermore, filtering removes some part of the total flavour of the juice. Thus, in a clarified juice one can have a maximum eye appeal but a flavour that is not typical of any variety.

On the other hand, in crushed apple juice the fresh fruit flavour can be very good, but the eye appeal is not strong and many do not like the particles of suspended solids in this juice. As a compromise between these two, experiments have been conducted and samples packed in order to obtain the reaction of the commercial trade to a new type of juice that retains the natural colour and flavour, and which is opalescent in appearance. For want of a better word, this juice has been called " natural " apple juice, as it is thought that this juice is as close to the natural contents of the apple as anything that has yet been produced. This is a similar idea to that recently reported by C. S. Pedersen (8, 9). However, additional information has been obtained on suitability of varieties and adaptation of the process to commercial conditions.

In the manufacture of natural juice, the apples are sprayed with ascorbic acid as they enter the hammer mill. The pulp is pressed in a hydraulic press with racks and cloths. The resulting juice is strained; de-aerated if desired, pasteurized, and passed into the filler. The remainder of the process is the same as for clear juice.

The amount of ascorbic acid required at this point has to be previously determined. To avoid dilution, the ascorbic acid for spraying should be dissolved in previously pasteurized and cooled juice. The volume of spray may be varied, satisfactory results being obtained with amounts around 150 ml. for each 33 lb. of fruit. It has been found with apples of the McIntosh variety that are still crisp and at firm eating-ripe maturity, that 20 mg. of ascorbic acid per 100 g. of fruit will give a residue of 1 mg. in the juice after it is pressed. If 1 mg. is present, this juice can be held for periods up to half-an-hour before being de-aerated and pasteurized. Jonathan apples in over-ripe condition required 35 mg. However, in ripe condition it is expected they would require an amount similar to McIntosh in good condition. Satisfactory products have also been made from Winesap and Stayman varieties. So far, it does not appear that this process can be used economically with varieties containing a large amount of oxidative enzymes, such as Newtown, Rome Beauty or Delicious, nor can it be used with any varieties that are past their prime eating maturity. However, for varieties such as McIntosh, which have a mild but delicate flavour, it is thought that this type of juice offers considerable promise.

It is interesting to note also, that by the use of ascorbic acid in this product, a precipitation of colloids is prevented and the opalescent character is maintained. In centrifuging at 3,300 revolutions per minute for 5 minutes, only 0·3 per cent. of solids was obtained. In samples that have been incubated at 50°-75° F. for 4 months, additional precipitate has accumulated, just as precipitates accumulate in orange or grapefruit juice, but this is quickly dissipated into the juice upon shaking.

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* See also p. 65.

The reaction of the trade to semi-commercial samples has been favourable. Much of the success of the pack will depend on the maintenance of at least 1 mg. of reduced ascorbic acid in the extracted juice and a rapid continuous operation. Fortification with ascorbic acid is an added protection.

Equipment for apple juice processing

(*a*) *Clarified juice*

(1) Washer: Apple trees receive a relatively large application of spray during the growing season with the result that spray residues are present on the mature fruit. In addition there is dust, etc., which should be kept from entering the final juice. Consequently it is advisable that the apples pass through an acid bath washer. Fortunately the apples are made into juice immediately and therefore can receive a much hotter treatment than apples that are intended for fresh marketing and which may need to be stored for several months. One per cent. hydrochloric acid at a temperature of 130° F. will generally give an efficient wash. These washers (Fig. 37) are usually wooden tanks with a distribution system on top consisting of a wooden channel and plate glass baffles to distribute the acid above the fruit. The apples progress through the machine on a positive wooden conveying system. The acid is pumped with a hard rubber pump and the tank is heated with a stainless steel steam coil.

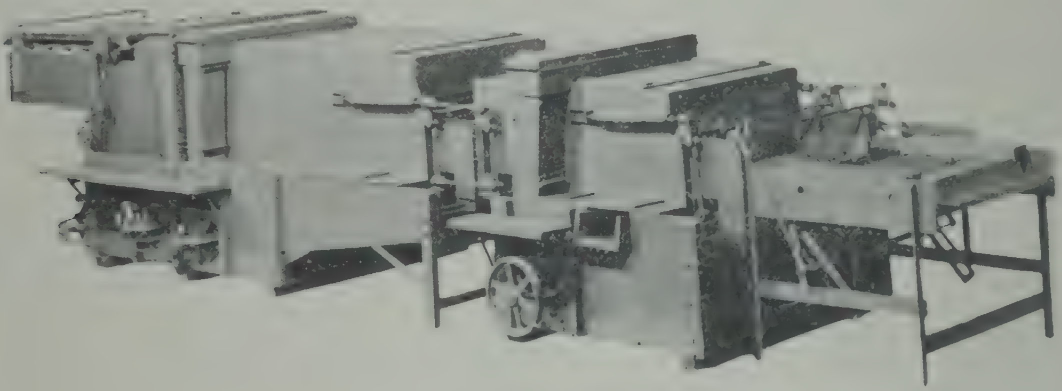

FIG. 37.
Acid bath apple washer.

(2) Stainless steel hammer mill: This mill is of the fixed hammer type. The hammers are made of $\frac{1}{2}$ by 2-inch stainless steel bars and are spaced an inch apart on the shaft with stainless steel ferrules. The shaft carrying the fixed hammers revolves at 1,750 r.p.m. and requires 15 horsepower (h.p.) where a capacity of 6 tons per hour is being handled. A half-round perforated screen in the bottom of the mill is fixed so that it is easily removed for cleaning or for changing in size. The perforations in this screen vary from $\frac{3}{8}$ inch up to $\frac{3}{4}$ inch. The size of screen used is determined by the maturity of the fruit being handled. In the early season while the apples are hard and crisp, the $\frac{3}{8}$ inch screen is used, while the larger screens are used with more mature apples. A stainless steel hammer mill is preferred to the grater type, as it has large capacity, is easy to clean and grinds the apples to a more even-sized pulp. The Rietz disintegrator, however, is proving popular in Californian factories.

(3) Hydraulic press and press room: The size of press indicated in Fig. 31 is one with an 18-inch ram and 60-inch racks. A ram of this size should be capable of developing 318 tons total pressure with 2,500 p.s.i. on the pump. In order to aid sanitation in the press room

nylon cloths are being introduced while plastic racks may replace wood.* The wooden collecting trays are now being covered with stainless steel. The arrangement suggested in the drawing is probably the simplest for efficient and hygienic large scale operation. If the floors and walls are made of suitable acid-resistant material that is easily cleaned, it should be possible to keep the whole room in an acceptable sanitary condition.

(4) Piping: From the press to the various items of equipment and to the filler, stainless steel piping and equipment has been indicated. It is not necessary that this equipment should be stainless steel, but it should be a nickel-bearing alloy without a high copper content, or glass, or hard rubber. It is necessary to avoid copper as small amounts such as 46 parts per billion have been shown to have a destructive effect on ascorbic acid. All the piping should be connected with sanitary joints that can be quickly dismantled so that the lines can be thoroughly cleaned.†

(5) Tanks: Wooden tanks are shown in the drawing for reasons of economy, although stainless steel is more suitable as a material. Each of the first three tanks, that is, T, T1 and T2, should be equipped with a stainless steel heating coil so that the most efficient temperature may be obtained during clarification.

(6) Pressure filter: A round pressure filter equipped with filter plates covered with stainless steel cloth can be used. There are three especially good features in this type of filter. First, the cylindrical shape with a heavy, reinforced, removable head makes possible the use of high pressures without leakage, thus ensuring large capacity. Secondly, it is of all-metal construction so that it can be kept in a sanitary condition. Thirdly, the stainless steel woven cloth is much easier to handle from a maintenance standpoint than cotton filter cloth. The stainless steel cloth does not shrink, is easy to keep in place, and is not a breeding ground for organisms.

(7) Pasteurizer: A suitable pasteurizer is one in which two stainless steel cylinders, 6 feet long, are placed inside one another, the ends being sealed with brass castings and rubber gaskets, and provision made for juice to flow between the cylinders. These cylinders are located inside a 12-inch steel tube equipped with ends which can be quickly opened. Steam enters at the outside near one end, flows along the outer stainless steel cylinder and thence down the inside of the inside cylinder. With a steam pressure of 5 lb., about 440 gallons of juice an hour can be heated from 40° F. to 186° F. These sterilizers have been in general use in the apple juice industry of British Columbia for several years. They are controlled by regulating the by-pass on the pump supplying the pasteurizer with juice and by a self-activated control whose bulb is in the juice line flowing from the pasteurizer and which activates the valve on the steam supply to the pasteurizer.

(*b*) *Crushed apple juice*

The equipment for washing and trimming apples for the crushed type of juice is the same, up to the point where they are milled, as in the clarified juice process. From this point, in the crushed juice procedure there are some differences in equipment. These include a rough slicer to cut the apples into about one inch slices, a Schwarz comminutor-extractor, and a de-aerator. The slicer cuts the apples into large pieces that are easier for the Schwarz disintegrator to handle. This machine grinds the apples to a very fine pulp and extracts the juice. The vessel where the juice accumulates is sealed to prevent entry of outside air and is directly connected with stainless steel tubing to the de-aerator. Accordingly, after the juice is extracted only a few seconds elapse before it enters the de-aerator.

The function of the de-aerator is to remove the dissolved gases, especially the oxygen, in the juice. It is claimed with crushed juice that a vacuum of 29·4 inches in the de-aerator is necessary to preserve a desirable colour and flavour. Because of this high vacuum, trouble is encountered from foaming and this has necessitated trial of several types of systems for distributing the juice in the de-aerator in a thin film. It is not known if a de-aerator as described in the equipment for natural apple is suitable for the crushed type. In this latter de-aerator a shaft passes through the top of the machine in a special gland. This has been operated with a vacuum of 28·5 inches. The maintenance of a vacuum of 29·4 inches requires very efficient equipment, involving a steam jet and barometric leg. A mercury barometer is required to make compensation for variations in barometric pressure.

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* The editor of this bulletin has made extensive trials in 1949 with British made nylon cloths for the pressing of blackcurrants and apples with remarkable success. Plastic racks were not so satisfactory, but their use, when the correct type of plastic has been determined, would appear to offer many advantages over wood.

† Pyrex glass piping is being increasingly favoured for transference of juice in English factories.

Homogenizer : It has been mentioned in the process for crushed apple juice that 3 to 10 per cent. of suspended soluble solids is included in the juice. Some operators have thought that this suspended matter is too granular to be attractive to the consumer. The particles are usually of sufficient size to settle to the bottom of a glass in a few minutes after processing. Consequently this process now includes a homogenizer that works at about 2,000 lb. pressure and completely breaks up the small particles of apple flesh in the juice. The homogenized juice, although containing the same amount of suspended solids, is so smooth that no particles can be detected on the tongue and the particles remain in suspension for long periods. There is, however, still some disadvantage from the standpoint of eye appeal, for the tiny particles that remain continue to cling to the walls of a glass and may be considered unattractive.

If a homogenizer is to be included in the equipment for crushed juice, it does not appear that the expensive Schwarz equipment is needed as the preliminary disintegrator. A crushed type of juice has been made in the Summerland Fruit and Vegetable Products Laboratory by using a conventional apple juice hammer mill for crushing the apples and passing the pulp through an expeller-extractor as used in tomato juice manufacture. This juice was passed through the de-aerator, through a homogenizer, pasteurizer, and filled into cans, capped and cooled. The yield by this method with McIntosh apples was 35 to 40 per cent. The residue when hydraulically pressed produced sufficient clear juice to provide a total yield of about 10 per cent. greater than if the pressing had been done to produce clear juice.

(*c*) *Natural apple juice*

The equipment used for natural apple juice is similar to that for the clarified beverage except that a de-aerator, strainer and sprayer for ascorbic acid are added and the storage tanks and filters are deleted.

De-aerator: In Fig. 38 the de-aerator with a motor at the top with a shaft in a vertical position is shown. This de-aerator is patterned after a design of Geo. N. Pulley (11). The vertical shaft passes through a special gland in the top of the de-aerator to a point about one-quarter way down the body of the de-aerator. At this point a flat, stainless steel disc about 10 inches in diameter is attached to the shaft. There is a protective ring around the perimeter of this disc about an inch high and sloping towards the centre shaft, the angle formed with the disc being about 45 degrees. At the point of this angle, holes are drilled through the protective ring. These holes are about an eighth of an inch in diameter and are spaced an eighth of an inch apart. Thus, as the juice is constantly drawn into the de-aerator by the vacuum and deposited on this revolving disc, the centrifugal force throws the juice against the protective ring and the juice is in turn distributed through the one-eighth-inch holes to the inside wall of the de-aerator. Here it runs down in a thin film which facilitates the removal of dissolved gases. The juice is constantly withdrawn from the de-aerator by a stainless steel turbine pump and passed through a pasteurizer. Vacua varying from 25 to 28·5 inches have given juices of satisfactory colour. This case is not exactly parallel, however, to that of crushed juice, as in the natural juice ascorbic acid has been added to prevent oxidation. The new type of juice has been made without the use of a de-aerator but results are more consistent when the machine is used. De-aerated juice is definitely easier to fill as foaming is eliminated.

Strainer : Instead of a filter, the new type of juice requires only a strainer that will remove large particles. A strainer that is proving satisfactory under commercial conditions contains screens of 20, 40, 60 and 80 mesh.

Sprayer : 75 p.s.i. air pressure was used experimentally to atomize 150 ml. of ascorbic acid solution in the hammer mill in 30 seconds, while 33 lb. of fruit were being ground.

Of the three juices, the natural type requires the least equipment and is easiest to produce with the exception of regulating the amount of ascorbic acid. After its extraction no storage tanks are required for the juice. There are no problems of clarifying with tannin and gelatin or enzyme preparations, and all filtering problems are avoided.

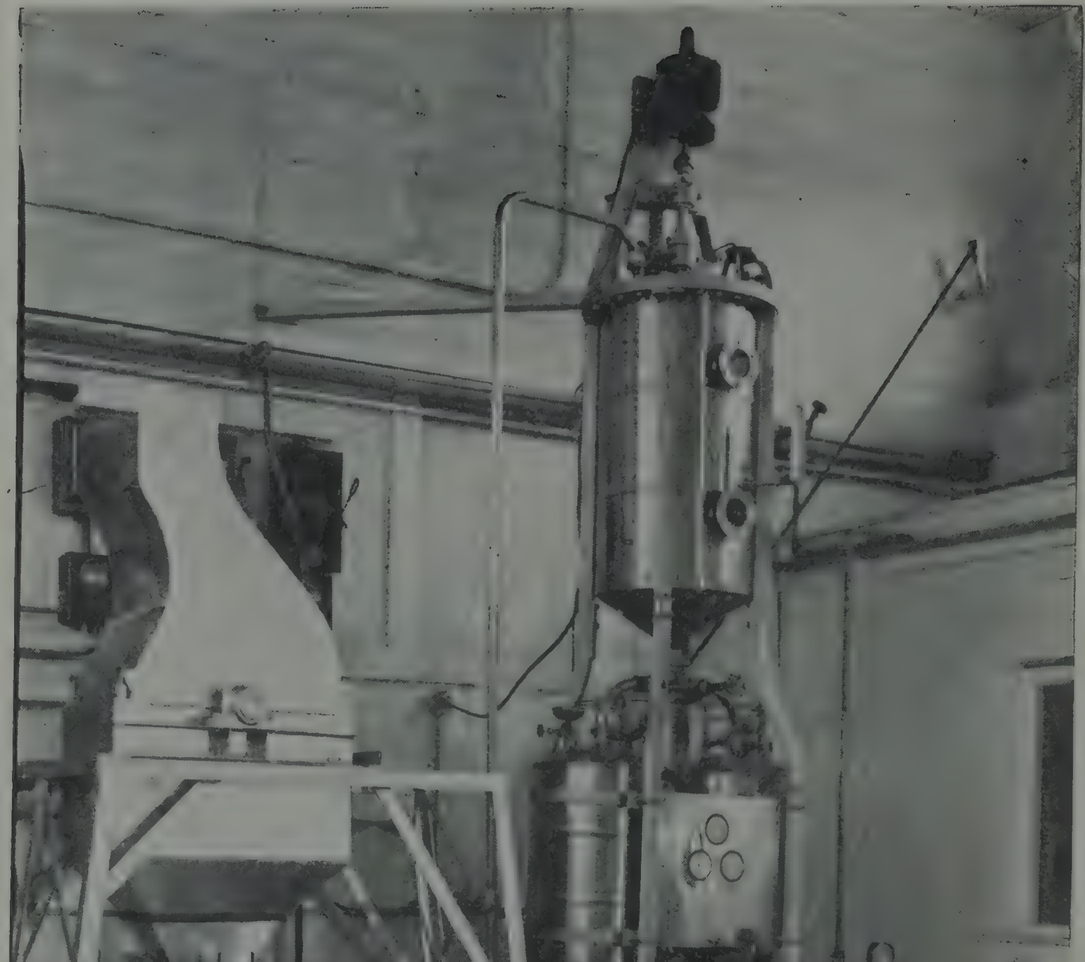

FIG. 38.
De-aerator for juices.

Clarification of apple juice

Apple juice may be clarified by one of several methods, such as (*a*) tannic acid and gelatin to form a flocculent precipitate, (*b*) pectic enzymes, (*c*) a combination of tannin and gelatin simultaneously with enzyme action, (*d*) centrifuging and finally filtering. The first three methods can give a relatively clear juice which is passed through a filter using diatomaceous earth to ensure the removal of all small particles.

Tannin and gelatin clarification

To clarify apple juice with tannic acid (tannin) and gelatin, stock solutions are employed for trial tests. These are used with quart samples of the product to be clarified and are as follows :

1. Tannin : 9·5 g. to 1,000 ml. water.
2. Gelatin : 21·25 g. to 1,000 ml. water.

The tannin is easily dissolved in water, while the gelatin should be made into a soft mass with cold water and the solution completed by boiling water.

If it is desired to preserve these solutions for more than a few days, preservation may be effected by using alcohol to take the place of part of the water. In this case, 200 ml. of 65 O.P. alcohol is used with 800 ml. water.

Trial amounts of these solutions are used per quart as indicated in Table 4. It is important that the tannin be added first and the juice thoroughly stirred. The gelatin is then added in a thin stream with vigorous stirring.

TABLE 4

TRIAL AMOUNTS OF TANNIN AND GELATIN SOLUTIONS

Test number	Trial amounts		Amounts per 100 galls.	
	Tannin (Solution 1)	Gelatin (Solution 2)	Tannin	Gelatin
	ml.	ml.	oz.	oz.
1	12	5·0	1·5	1·5
2	12	6·6	1·5	2·0
3	12	8·3	1·5	2·5
4	12	10·0	1·5	3·0
5	12	11·6	1·5	3·5
6	12	13·3	1·5	4·0
7	12	15·0	1·5	4·5
8	12	16·6	1·5	5·0
9	12	18·3	1·5	5·5
10	12	20·0	1·5	6·0

The least amount of gelatin giving the desirable clarification should be selected. Usually only the first four or five sets are necessary, but if satisfactory clarification is not obtained with any of these the complete series should be tried.

After these trials have been made the equivalents given under the heading " Amounts per 100 gallons " are added to the large batch to be clarified ; that is, if No. 3, using 8·3 ml. of gelatin and 12 ml. of tannin was found to give the best clarification, then 2·5 oz. of gelatin and 1·5 oz. of tannin would be used for each 100 gallons of juice. Both solutions should be prepared in water in the same manner as that used for the stock solutions. Only enough water is used to dissolve completely the tannic acid. The gelatin should not be too thick. For example, if 15 oz. of gelatin are required to a 500-gallon tank of juice, 1 to 1½ gallons of hot water should be used. The gelatin may also be dissolved in hot juice from the pasteurizer. A heavy flocculent precipitate will appear in a few minutes and will settle completely overnight.

The filter aid may be added to the juice as soon as the flocculent precipitate appears, or the precipitate may be allowed to settle and the clear juice drained from above the precipitate. The simplest method, however, is to add up to 5 lb. of good diatomaceous filter aid for each 100 gallons of juice to be filtered as soon as the coagulum appears. However, if this method is employed, greater filter capacity is required than when the sludge is allowed to settle.

In order to keep the filter aid continuously in suspension so that all juice going to the filter will contain a uniform amount of filter aid, agitators are necessary. Several portable models are available which use an extended shaft with a propeller attached to the shaft of an electric motor. Stationary baffles can also be placed in the tanks.

Tannin and gelatin clarification is most suitable when the apples are slightly immature, but when they become over-ripe clarification often becomes difficult. For slightly over-ripe fruit, processors use heating coils to aid the reaction between the tannin and gelatin. Eventually, however, as the season progresses, the operators change to a combination of tannin and gelatin with an enzyme, or the enzyme alone.

Enzyme clarification

With British Columbia varieties the best results are obtained when the juice is heated to 80° to 85° F. 0·1 per cent. of the enzyme is then added to the tank and the juice thoroughly agitated. Clarification is usually complete in 8 hours.

Tannin and gelatin and enzyme clarification

It is claimed that by using one-half of the tannin and gelatin required for clarification with one-half the amount of the enzyme that would be used if enzyme were the sole clarifying agent, juices can be cleared that would be difficult to clarify with either of these agents alone (14). It is also claimed that a more compact sediment is obtained so that there is less loss of juice.*

Centrifuging

A rough clarification can be obtained with a Super centrifuge. However, with the latest 1946 model with which the writers have had experience, it was thought that the capacity per hour was not sufficiently high considering the cost of the machine. Also the machine required a considerable amount of labour for cleaning and reassembling. Samples of juice that were centrifuged and filtered did not have a significantly better flavour than samples clarified with the tannin-gelatin or enzyme preparations.

Filters

Plate and frame filters have been in common use, but they require a great deal of labour and juice is lost through leakages. The all-metal filters that are now on the market are proving very popular. The advantages of these filters have already been discussed under Apple Juice Equipment (pages 49, 54).

Fortification of apple juice with ascorbic acid

The Canadian Meat and Canned Foods Act states as follows :

" The fortification of apple juice with ascorbic acid (vitamin C) is covered by Patent No. 395770. The patent rights have been surrendered to His Majesty. Processors may apply for details of the equipment prerequisite for licensed use of the patent. Application for licence should be certified by the local inspector. The product shall contain not less than 35 mg. of biologically active ascorbic acid per 100 c.c. of juice at any time within twelve months of being packed. This shall be determined by the indophenol titration method and the product shall be labelled—' Contains not less than 35 mg. of Vitamin C per 100 c.c.' The establishment number and the date of packing shall be embossed on each container."

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* For Swiss methods of clarification, see Editorial Note 1, p. 62.

In Fig. 31, 500 gallon tanks are shown. On page 51, it was explained that fortification with ascorbic acid was performed in these tanks. This is assuming that the bulk juice is to be fortified, in which case the crystalline ascorbic acid in the form of fine crystals or powder is added to a tank of juice and the juice gently agitated until the acid is dissolved. Only brief submerged agitation is required.

The over-all loss on canning and twelve months' storage should not exceed 10 mg. of ascorbic acid per 100 ml. of juice. Consequently it should be necessary to fortify to only 45 mg. per 100 ml. or to the rate of 7¼ oz. per 100 Imperial gallons. Frequently, however, processors use as much as 8 oz. per 100 gallons of juice, which is at the rate of 50 mg. per 100 ml.

A second method of fortifying with ascorbic acid is by adding tablets directly to the can. The loss of acid in this case is less than when fortifying in bulk. However, uniformity between individual tins is often lacking and the cost of the tablets is comparatively high. A further disadvantage is that differently sized tablets are required for the cans of various sizes.

A third method is to introduce concentrated solutions of ascorbic acid directly into the cans just prior to filling. The solute in this case is pasteurized apple juice. This requires additional labour or an expensive dispenser. Retention of ascorbic acid by this method is excellent provided satisfactory filling and pasteurizing conditions are met.

Prevention of oxidation in the juice prior to addition of ascorbic acid (such as in the crushed type and natural type juice) reduces the loss of ascorbic acid by several milligrams. Unless an inert gas is used in the headspace, it is essential to fill the cans quite full. Cooling the cans promptly and thoroughly with subsequent storage at a temperature below 70° F. assists in retaining ascorbic acid, colour and flavour. (For further details concerning ascorbic acid fortification of apple juice, reference should be made to the comprehensive studies of Strachan (12) and Johnston (5). Procedures for the fortification of apple juice with ascorbic acid under commercial conditions have also recently been described by manufacturers of ascorbic acid.

Storage of apples for juice production

Cold storage

With many of the apples used for juice production being in the so-called cull grade, cold storage cannot be generally recommended for all varieties. In the case of McIntosh, where there are frequently stem punctures and other injuries to the skin, the percentage of rots if cold stored is too high and a great deal of labour is required to remove them. On the other hand, winter varieties and late winter varieties such as Newtown, Winesap and Stayman Winesap can be cold stored to advantage. In this case the cold storage should not be protracted as apples sometimes take on a cold storage flavour towards the end of the winter months and this flavour is carried into the juice. Consequently, if cold storage is used, the apples should be out by the end of February.

Storage at normal temperatures

At the peak of apple juice manufacturing during the autumn months, it is a frequent practice to store apples in bulk in bins. (Fig. 39.) These bins are best located outside until there is danger from frosts, but indoors during the periods of frost. In either case the bins should have smooth acid-proof floors and walls that can be thoroughly cleaned. Provision for circulation of cool dry air is desirable. A maximum depth of 4 feet of apples avoids some storage troubles. As water transportation is one of the most efficient and economical methods of delivering apples to the commencement of the juice line, it is good practice to have the floors of the bins slope towards a drain immediately outside the bin. Automatic feeding into the drain is facilitated by opening a hinged section in the bottom part of that side of the bin next to the drain. Spent cooling water from adjacent cold storage plants is often used for this purpose. If water is costly, a large proportion can be recirculated.

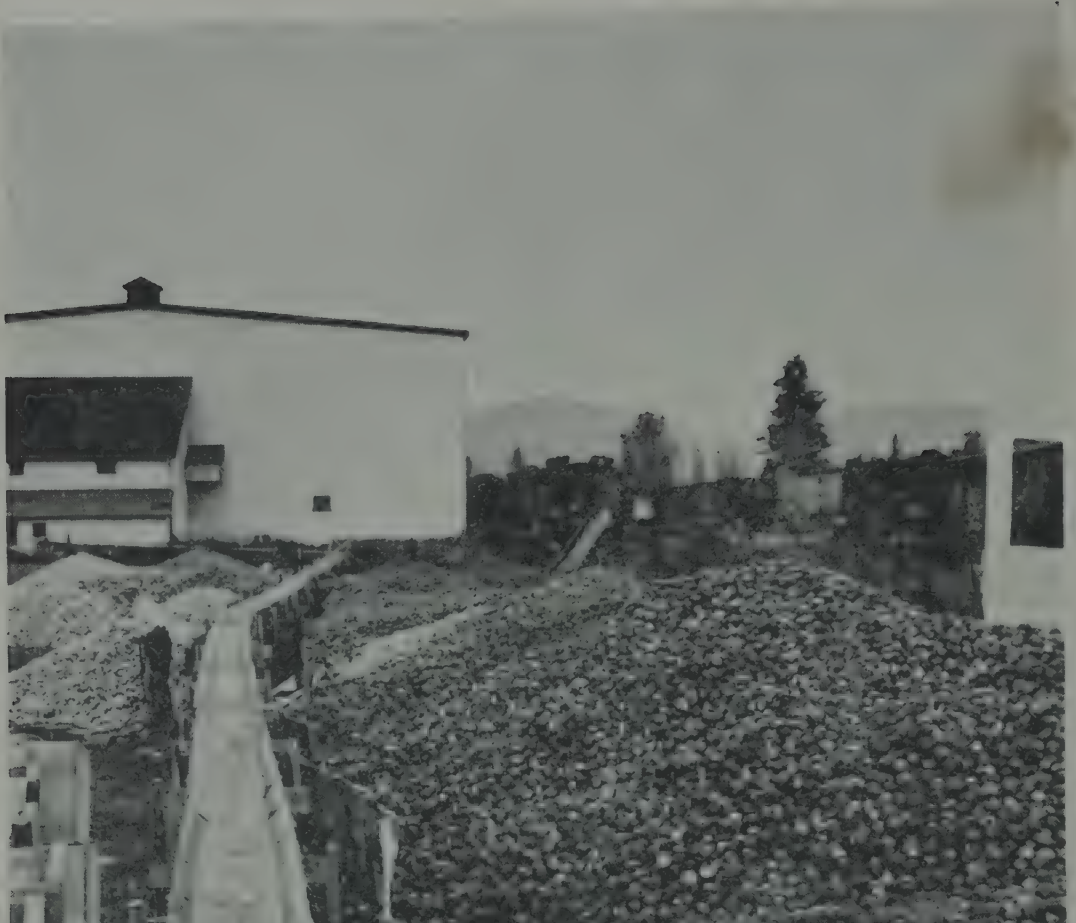

Fig. 39.

Apples for juice in outside bin storage.

Blends of apple juice with lime, grapefruit, raspberry and blackcurrant

Blends have been prepared of lime, grapefruit, raspberry and blackcurrant juices with apple juice. In each of these blends an effort has been made either to improve the apple flavour or develop a new flavour with consumer appeal.

Lime juice should be blended with a mild apple juice such as that produced from the Delicious variety. The lime juice increases the acidity and only sufficient should be used to contribute a mild lime flavour to the blend. Experimental packs have been tried containing 2 to 6 per cent. lime juice. The commercial pack usually contains the lower limit of lime, Montserrat lime juice being imported in 40-gallon barrels for this purpose.

Grapefruit juice has been blended with apple juice in experimental quantities only. However, 20 per cent. grapefruit with 80 per cent. apple has given a pleasantly flavoured juice.

Raspberry juice for blending with apple is best prepared by freezing the raspberries with 10 per cent. sugar and holding in frozen storage until the apple juice season. The juice is then pressed from the raspberries (10) and mixed with apple juice which is ready for pasteurization. For the first pressing, cold raspberry material is used, whilst for the second pressing the pomace is heated to 145° F. with an equal weight of apple juice. At the Summerland Laboratory one part of raspberry to three parts of apple juice has given a desirable flavour.

Blackcurrant juice also makes a pleasant blend with apple juice. If undiluted, 15 to 20 per cent. gave a product considered better than either juice by itself.

Esselen, Powers and Fellers (3) have reported that an attractive apple juice-blackcurrant blend can be prepared by pressing blackcurrant pomace mixed with apple juice. The resulting juice was found to contain from 25 to 40 mg. of ascorbic acid per 100 ml.

Methods of extracting blackcurrant juice from the fruit are given in Chapter II, page 32.

GRAPE JUICE

The commercial production of grape juice in Canada for the years 1942 to 1946 inclusive is as follows :

TABLE 5

PRODUCTION OF GRAPE JUICE

Year	Quantity
	galls.
1942	690,917
1943	234,927
1944	372,101
1945	504,821
1946	783,438

Preparation of grape juice

Grape juice is preserved by a number of methods such as pasteurization, cool temperature storage at 28° F. to 30° F., cold or freezing storage, filtering through a germproof filter, storage under high pressure carbon dioxide gas, concentration of the juice until the soluble solids are sufficient to effect preservation, and finally some juice is preserved by chemicals.

Only preservation by heat, cool storage and frozen storage for deposition of argols will be dealt with here. The discussion is confined to the Concord and closely related varieties as these are the varieties mainly used for juice in Canada.

The grapes are harvested when the total soluble solids content is at least 18 per cent. as estimated with a refractometer. Grapes for juice should also be of the best quality in other respects. They should not be green nor should they be too ripe. The grapes are washed and stemmed, crushed, and slowly heated to a temperature of 140° to 145° F. Heating to this temperature releases colour and acid, and facilitates pressing. At least 140° F. is required to release the colour while there is a possibility of obtaining harsh flavours if the temperature exceeds 145° F. The juice is pressed while hot either in a hydraulic press, employing the usual racks and cloths, or in basket presses. The expressed juice is strained and reheated to 170° to 190° F. At this point storage is necessary to allow the argols or crude tartrates to separate. One of the following two processes may be used to accomplish this separation :

(a) The heated juice may be filled into warmed carboys, leaving no headspace and using a paraffin-coated cork. Cooling is as rapid as practicable without breaking the glass. Four months' storage at least is then required for the deposition of argols.

(b) The heated juice is cooled with heat exchangers until it is 29° to 31° F., and run into large tanks (some approximate 10,000 gallons). The room containing these vats is maintained at 28° to 30° F. With this process one month's storage is sufficient to achieve separation of the argols. In filling large tanks, care should be taken to see that the juice does not become aerated. To ensure holding the juice at the recommended temperature, the tanks may be equipped with refrigerated expansion coils.

When carboy-stored juice is to be bottled* the clear juice is siphoned or decanted from the precipitated argols and sludge. In the case of juice stored at 28° to 30° F. the temperature is raised to 45° F. for two days. This higher temperature allows some of the acid to go back into solution. Then the top two-thirds of the tank is siphoned or decanted. This juice is not filtered in order to preserve the best colour and flavour. The addition of sugar will depend upon the nature of the grapes and the demands of the market. The juice is then de-aerated and pasteurized. The sludge from the carboys or the bottom third of the large tanks has up to 3 per cent. diatomaceous earth added as a filter aid before filtration. In pasteurizing, the juice is pumped through a flash pasteurizer to heat the juice to 170° to 185° F. The bottles or cans† are completely filled so as to eliminate any possible oxidation by air contained in the headspace. The containers are tipped on their sides for 2 to 5 minutes and then cooled. In cooling bottled juice the first sprays should be warm water, but the water should be progressively cooled until quite cold water is applied. For canned juice, the temperature should be reduced to 100° to 110° F. as quickly as is practicable. Although this quick pasteurization at 170° to 185° F. is used successfully under commercial conditions, some manufacturers still heat the juice to 165° to 180° F., fill into bottles and again pasteurize for 15 to 20 minutes in a water bath heated to the filling temperature. In this case, $\frac{1}{8}$ inch headspace is allowed and cooling is the same as for the quick process. This same precaution with cans would add a 10 to 15 minute process at 212° F. The additional heat treatment does not appear necessary from the standpoint of preservation and it affects the colour and flavour deleteriously. After labelling and casing, the juice will keep best in a cool storage.

Equipment

Machines and tanks of stainless steel or other white metal alloys as suggested for tomato and apple juice are suitable for handling grape juice. Care should be exercised to prevent contamination of the juice by iron or copper equipment.

EDITORIAL NOTES.

1. The latest Swiss method of fruit juice clarification

The following description of up-to-date Swiss methods for dealing with the clarification of apple juice has been translated from *Schweizer Obst* (August 1948, pp. 4-8).

(i) Juice flowing from the press should always be passed through a sieve to remove large particles of tissue.

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* For the sake of completeness, the *bottling* of grape juice is included in this Chapter.

† Special enamel cans have been used to a limited extent in the United States. However, the glass pack continues to be the most important.

(ii) The juice from sharp apples can often be clarified in a short time by adding second or even third pressings without any clarifying agents whatever.

(iii) The addition of 8-15 per cent. sharp pear juice (Schiedmost) to an apple juice will often clarify the bulk in a short time. Even if completely satisfactory clearing is not obtained by the method, it has been found that the previous use of pear juice facilitates the later action of gelatin.

(iv) *Use of sharp pear juice:* A preliminary test will show the optimum proportion to use for clarification. 100 ml. of the bulk juice should be placed in each of six cylinders and 1, 3, 6, 9, 12, 15 ml. of the clarifying juice added to each cylinder. Comparison of effectiveness can only be gauged after two or three hours; it is necessary to pass the samples through a filter paper, as an improvement in filtering often occurs before there are any visual signs of clarification. When the correct proportion of pear juice is added to the bulk, the mixture should be allowed to remain for 10-13 hours before attempting to filter it. For the preliminary test to be most informative, the test juices should be brought to and maintained at the same temperature as that of the main bulk. Failure to achieve clarification by this means indicates the necessity of adopting other methods in as short a time as possible.

(v) *Enzyme clarification:* The enzyme process is usually applied only to the juice, but there is the possibility of obtaining an increased colour yield from grapes if the enzyme is mixed with and allowed sufficient time to react with the milled fruit. When used with juices, enzymes work only slowly at temperatures below 10° C. and are largely destroyed when exposed to temperatures above 40° C.

Addition of excess enzyme does not harm the juice but is uneconomical. It may be taken that the maximum addition necessary will be 0·15 per cent. of Pectasin W (i.e. a single strength enzyme similar to Pectinol A and Filtragol as used in U.S.A. and Europe before and during the last war). If large quantities of juice are being treated, some idea as to the amount of enzyme that will be needed should be determined. A simple preliminary test is available or this purpose.

Equal quantities of juice and absolute alcohol are shaken together in a standard test tube. The contents are allowed to stand for 20 minutes or longer and the pectin layer formed on top of the liquor is inspected and its depth measured. A rough and ready guide to the quantity of pectin in the juice is afforded by the depth of the pectin layer:

2-4 mm. indicates a slight pectin content.
5-25 ,, ,, ,, medium pectin content.
30-50 ,, ,, ,, considerable pectin content.

The addition of enzyme for each of these three grades of juice can be calculated as under:

Slight pectin content in juice—add 0·02-0·045 per cent. enzyme (wt./vol.).
Medium pectin content in juice—add 0·05-0·075 per cent. enzyme (wt./vol.).
Considerable pectin content in juice—add 0·08-0·15 per cent. enzyme (wt./vol.).

A more exact preliminary test is also available.

Six cylinders are filled with 100 ml. each of juice. 10 g. of single strength enzyme are dissolved or suspended in one litre of water to provide a 1 per cent. stock solution. A pipette is used to add respectively 2·5, 5, 7·5, 10, 12·5 and 15 ml. of the enzyme solution to each cylinder. The samples should be well mixed and examined after 1-2 hours by visual observation or a filtration test. Should no sample show adequate clarification, the gelatin method must be attempted.

For bulk enzyme action, the required amount of enzyme should be suspended in a little of the juice which has been raised to 30°-40° C. and maintained there for one hour. This volume of enzyme suspension should be mixed into a larger quantity of juice and adequately incorporated in the bulk juice for clarification. Pectin decomposition should be finished after 8-10 hours if the temperature is approximately 10° C.

(vi) *Clarification with gelatin:* This method of clarification has the widest application for fruit juices. If the juice under treatment is known to be particularly low in tannin, 0·005-0·01 per cent. of tannin should be added to the juice before the gelatin addition. Excess of gelatin is very harmful to the colour and flavour of the juice and exact preliminary tests should always be carried out before treating the main bulk.

(a) Preliminary test: Six cylinders containing 100 ml. of juice each are treated respectively with 2·5, 5, 7·5, 10, 12·5 and 15 ml. of a 1 per cent. gelatin solution made up in the usual manner. No exceptional changes in temperature in the juice must be allowed during the test. The optimum treatment can be decided by inspection after 1-2 hours.

(b) Bulk clarification with gelatin: The optimum temperature for gelatin clarification is 8-15° C. Higher temperatures slow down the process, whilst lower temperatures often cause subsequent turbidities. The incorporation of the gelatin solution is more efficiently ensured if it is mixed with a reasonably large volume of the juice to be clarified before being agitated into the whole bulk. The juice should be allowed to stand for 8-10 hours before the clear liquor is pumped away from the deposit.

(vii) *Combined gelatin and enzyme treatment.* It may be found that some juices do not respond to economical doses of enzyme or gelatin when either is used alone. If conditions do not favour the early onset of fermentation, enzyme action is first carried out on the bulk juice and the preliminary gelatin test is then effected four hours later on the enzyme-treated juice. Should conditions, however, not allow for such delay, the juice is first examined for optimum gelatin addition by the usual small scale test. A pectin enzyme is added to the bulk juice in quantities indicated by the simple precipitation test before the gelatin is added to the bulk.

NOTES:

(a) When attempting to siphon clear liquor from a deposit, it is often an advantage to use a wooden float to rest on the liquid and to fit one end of the suction pipe through a hole in the float so that it protrudes for a short distance under the circular wooden surface. In this way, removal of solid materials can be largely avoided.

(b) In warm weather, fermentation may arise so quickly that the clarification cannot be effected before the evolution of gas completely prejudices its success. In such cases, some Swiss processors use 100 p.p.m. of potassium metabisulphite which generally inhibits the fermentation for a sufficient period without adversely affecting the clarification process itself.

2. American developments in juice production

Dr. M. A. Joslyn, of the Division of Food Technology, University of California, has provided the following information regarding the up-to-date position of apple juice in U.S.A. The proportion of clear and cloudy juices has remained unchanged since 1940. Less than half of the total production is in a cloudy condition, despite its superior flavour appeal. Most bottled products are clear, with the exception of one cloudy juice marketed under the name of "liquid apple". This is free from the usual brown discoloration of an oxidized juice and the initial flavour of the apple is retained to an exceptional degree. The Schwarz disintegrator is used to obtain the necessary consistency in the juice.

The normal process for cloudy apple juice is to grind the fruit in a hammer mill and express the juice in the usual way with cloths and racks. The expressed juice is lightly strained, de-aerated and flash pasteurized into enamel-lined cans which are sealed, sterilized in hot air and cooled.

An equally new development is the use of short time-high temperature sterilization with aseptic filling into pre-sterilized containers. Efficiently carried out, such a process can be used with lower temperatures and with the avoidance of a holding period prior to cooling. The juices so treated are characterized by very fresh flavours and aromas.

There still appears to be some doubt as to the necessity for de-aeration in the canning of apple juice. The use of ascorbic acid solely as a means of flavour improvement has not been widely adopted. One problem affecting the stability of enzyme clarified apple juice is the precipitation of pectic substances later in the life of the juice. The prevention of this deposition of solid materials has been achieved by the addition of small quantities of pectin before the final flash pasteurization, but the actual mechanism of this preventive action is not yet understood.

3. Comminuted apple juice (Schwarz Process and Equipment)

In recent years considerable publicity has been gained by apple juice products of a cloudy character which have been produced by the Schwarz comminutor-extractor. Considerable information regarding this plant has been given in this chapter by the Canadian authorities (p. 52), but at the end of 1948 information was forthcoming regarding the use of the Schwarz process and equipment in the juice and sauce industries, and this is presented below to amplify the information already given.

The key unit of equipment in the making of comminuted apple juice under the Schwarz process is the Schwarz comminutor-extractor. To minimize oxidation effects, this machine rapidly reduces the apples to a pulp and separates juice and desired solids from the pomace which contains the skin, seeds, core tissue and excess pulp.

Schwarz comminutor-extractors are available in two sizes: the model D-6 which is capable of handling 2½-3 tons of apples per hour, and the model D-7 which is capable of handling 5-6 tons per hour. Juice extraction ranges from 108-117 gallons per ton of fruit; and production of sauce from treated pomace ranges from 69-78 gallons per ton of fruit.

The making of comminuted apple juice requires careful selection of apples for variety, juice characteristics and prime condition of ripeness. Each shipment of apples should be inspected for defective material such as decay, worms, hollow core or other recognizable conditions which could affect either the colour or the flavour of the finished juice.

(*a*) *Preparation and Extraction.* Referring to the attached flow chart (Fig. 40) apples accepted for processing are first passed through an acid bath wash (1) where a clean dilute solution of hydrochloric acid, maintained at optimum temperature and acid strength, removes spray residues, wax, leaves or other contaminating substances. The apples pass from the acid bath through a washing machine (2) and spray rinse (3) to remove the remaining traces of acid from the fruit.

The apples move on to the sorting table (4) where they are graded and trimmed. Clean, sound apples pass from sorting table (4) into hopper (5) where they are picked up by elevator (6) and fed into chopper (7). To minimize the possibility of oxidation, chopped apples are conveyed rapidly from the chopper into and through the Schwarz comminutor-extractor (8). Here preparation and separation of high quality juice are rapidly carried out. The juice then enters a closed system for processing and the remaining materials drop on to conveyor (25) as pomace.

(*b*) *Juice Processing Line.* Following the juice line, after leaving the Schwarz comminutor-extractor and entering the closed system, the juice first passes through automatic control valve (9) which prevents air entering the system due to variations in flow. From here the juice passes through the piping system into detector (10) which actuates an alarm to warn plant operators of irregularities in juice production. The juice then enters the de-aerator (11) after which it is forced by pump (12) through pasteurizer (13) in which it is sterilized by heating rapidly to 200-210° F. Thereafter, the juice passes through feed tank (14), into the homogenizer (15) and then to filler (16) at a temperature of not less than 190° F. Filled containers move to closing machine (17), can washer (18), conveyor to hold cans for 3 minutes (19), can cooler (20), can dryer (21), labeller (22), case packer and sealer (23 and 24), and thence to storage.

(*c*) *Sauce Processing Line.* Returning to the pomace line, the material is carried by conveyor and elevator (25 and 26) to pulper (27) where sufficient water is added to facilitate the separation of seed, core tissue, and skin particles from the apple pulp. The latter then enters pump (28) and is forced through flash heater (29) into steam-jacketed pans (30) where water, sugar and citric acid are added according to formula to produce an appetizing sauce type product which may be used as a dessert or as fruit filler in bakery goods. From pans (30), the sauce is drawn off by pump (31) or by gravity if pans are raised, and is delivered to filler (32) at a temperature of not less than 190° F.; thence it is conveyed in the normal manner to closing machine (33), can washer (34), hold conveyor (35), can cooler (36) can dryer (37), labeller (38), case packer and sealer (39 and 40), and thence to storage.

4. Canned apple juice in England

The English pure fruit juice industry almost from its inception has used cans for apple juice. A new type of can was devised specially for this product as the open top can made from plate lacquered in the flat sheet did not provide sufficient cover for such an acid product. The "beverage cans",* as they were known, were given extra protection by being lined with a petrolatum type wax. The cans were provided with a cone-shaped top and a convex base to stand the pressure of the crown corking operation. The wax was heated to a temperature below 250° F. and pumped into the inverted cans. Waxes suitable for this protective purpose melt at about 160° F., so that juices cannot be filled into the cans at a temperature above 140°-150° F. This limitation is not serious with acid fruit juices, for the product can be flash pasteurized at a higher temperature and cooled to, say, 140° F. before being filled into the cans. This procedure affords a sterile pack.

What is open to some doubt, however, is the effect of the wax lining on the flavour of the juice. There is a feeling that the apple juice flavour is affected if only to a slight extent by contact with the lining. Although every effort has been made to discover new and better waxes, there is still room for improvement if canned apple juice is to develop at a commensurate rate with the bottled product.

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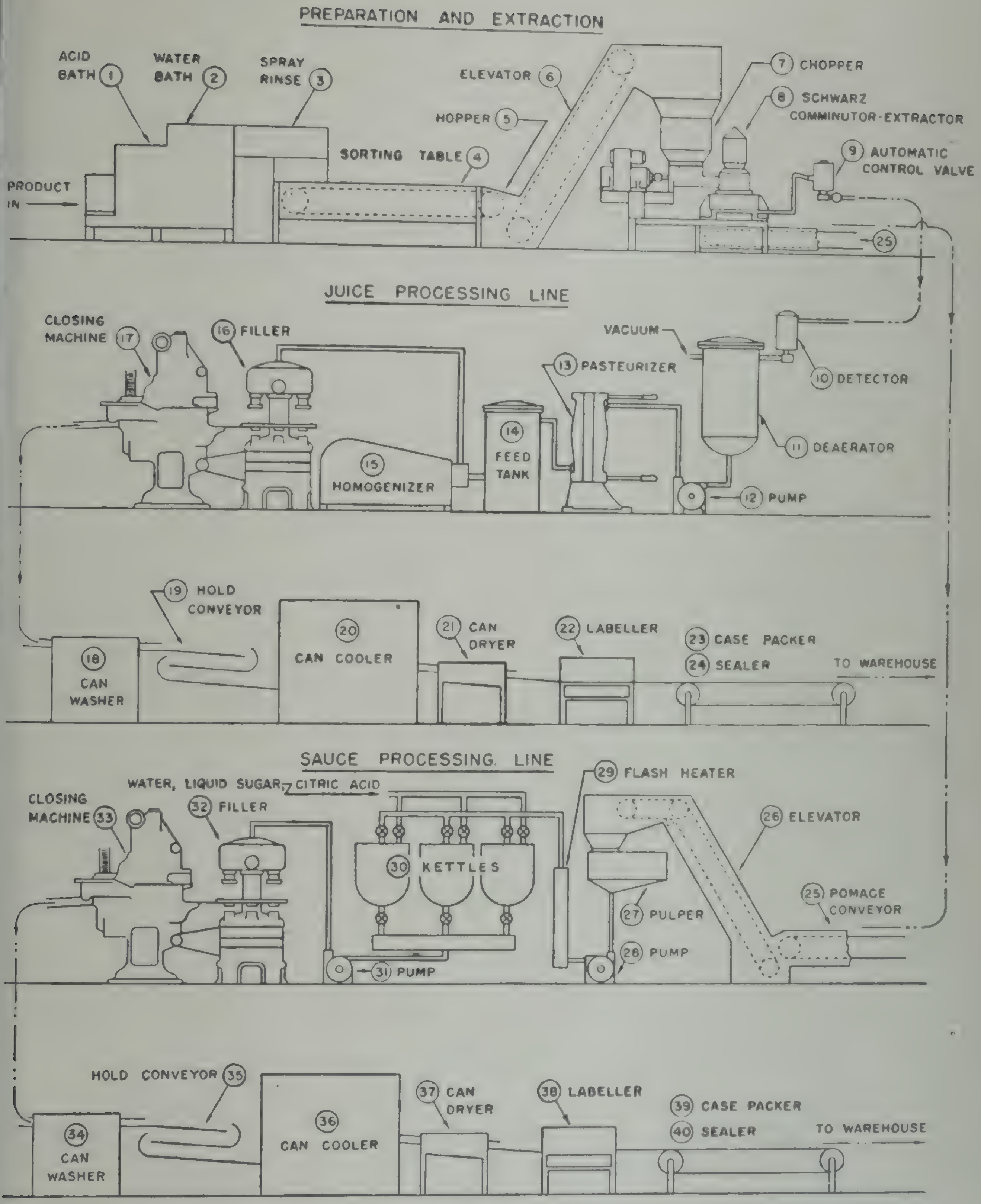

Fig. 40.

Flow diagram for comminuted apple juice.
(The Schwarz Engineering Company, Inc.)

CHAPTER IV

DE-AERATION AND PASTEURIZATION

By

C. Hunnikin

It is of interest to reflect upon the title of this chapter, for while it does not adequately describe the two unit processes now widely practised in the fruit products industry, the terms are commonly used by processors and technicians dealing with fruit juices. Both words are now established in the food industry and in the one instance a tribute to a great scientist is recognized. Some ambiguity is introduced by the use of these terms, for de-aeration should more appropriately be described as " de-gassing ", whilst there is a long-standing controversy concerning the correct use of " pasteurization " or " sterilization ".

DE-AERATION

Physical aspects

The commercial packer, having extracted the juice from the fruit, has to prevent, or at least retard, the adverse changes that may occur during the processing, packing and shelf life so that the consumer can enjoy the product and appreciate the natural characteristics originally present in the freshly extracted juice. These changes may be due to chemical reaction, but it is now recognized that the most deleterious effects arise from external factors, one of which is the absorption of oxygen.

In most instances the dissolved gases, mainly oxygen and nitrogen, are initially absorbed from the atmosphere, their proportions in solution being controlled by their solution characteristics and diffusion rates. Fruit juices contain between 85 and 95 per cent. of water and their physical ability to dissolve atmospheric gases can therefore be compared with water which at normal atmospheric temperature and pressure will absorb atmospheric gases up to about 2 per cent. by volume (excluding CO_2, relatively large volumes of which may be present and which originates in the fruit). When equilibrium between the water and the atmosphere is attained, the water is said to be fully saturated and it is found that approximately one-third of the total gas content is oxygen, the remainder being nitrogen. Thus, about 6-7 ml. of oxygen and 13-14 ml. of nitrogen are dissolved per litre. While this comparison of juice with water indicates the physical conditions at any given time, it does not take into consideration one essential factor. Oxygen is chemically reactive with some of the juice components, particularly in the presence of catalysts that may also be present. It will be apparent that this gas will be continuously and preferentially taken into solution so long as it is being assimilated by chemical combination with the various constituents of the juice.

Dissolved gases are taken into solution in proportion to the partial pressure they exert in the juice. Moreover, the solubility progressively decreases as the temperature is raised. If juice at atmospheric pressure and saturated with atmospheric gases is heated, the dissolved gases will be continuously liberated until the temperature of the juice reaches boiling point. When boiling point is attained virtually all the gases will have been driven from the juice.

Likewise, if the pressure over the juice is progressively reduced the dissolved gases will be continuously liberated until the pressure is equal to the vapour pressure of the juice, which condition is synonymous with boiling point, when again virtually all the gases will have been removed from the solution. If the pressure is further reduced then the juice will " flash " ; volatile constituents and water will vaporize and the temperature of the liquid will steadily fall to maintain equilibrium with the pressure prevailing in the system.

The development of de-aeration

Brevity is essential to enable a rapid conception of the origin and subsequent progress of de-aeration. When the results of laborious tests—and the conclusions drawn from them—are condensed to a few sentences, then accuracy of fact inevitably suffers and many qualifying factors are omitted. Therefore a comprehensive appreciation can only be obtained by detailed study of the original works to which reference is made in this chapter.

It is in the treatment of citrus juices that the value of de-aeration has been most apparent, for the process has directly contributed to the solution of two problems—(a) the prevention of " off flavours " and (b) the retention of ascorbic acid.

According to R. T. Will (67) the citrus by-products industry, established in California at the turn of the century, experienced many difficulties in the first ten years. Cruess (17) at the University Experimental Station was working on the utilization of culled fruit and a bulletin on the subject was published in 1915. At the other side of the United States, McDermott (48) was interested in the same problem. Although his paper was not published until 1916, the original work was done between 1911 and 1913. To quote from his original findings :

" It was found . . . that the removal of air dissolved in the juice . . . followed by pasteurization was sufficient to prevent this (flavour) deterioration for a considerable time."

Although the experiments and conclusions drawn by these pioneers revealed one of the causes of rapid deterioration in the quality of juices, it was not until 1925 that the juice products themselves attained commercial importance.

Joslyn and Marsh (32) reviewed a practical method of applying de-aeration by spraying the juice into evacuated tanks, a series of which were employed to enable continuity of feed to be maintained while previously filled tanks containing de-aerated juice were drained. While this semi-batch method was being introduced in commercial plants, Mottern and von Loesecke (46) were experimenting and developing in the laboratory a continuous method which proved simple and efficient. Their later work, in association with Pulley (39), revealed the methods which are the basis of current practice. In the process they describe, screened juice is drawn into an evacuated, inverted flask, sprayed on to the wall of the flask and by the time it has gravitated to the outlet connection de-aeration has been effectively accomplished. The liberated gases, having been collected at the apex of the inverted flask, are withdrawn through a central glass tube connected to a vacuum pump.

It has been shown that ascorbic acid is responsible for the relative instability of orange juice. Shillinglaw and Levine (54) measured its influence by subjecting samples of 2·0 ml. to absorption of O_2 for 4 hours at a temperature of 31·6° C. The results, briefly, were as follows :

Natural orange juice (not pasteurized)	absorbed	35	μlitres.
Natural orange juice (pasteurized)	,,	42	,,
Orange juice fortified with ascorbic acid (not pasteurized)	,,	67	,,
Orange juice fortified with ascorbic acid (pasteurized)	,,	110	,,

These data show that the juice to which ascorbic acid had been added took up oxygen considerably faster than did those to which ascorbic acid had not been added. It was also consistently found that the pasteurized juice with added ascorbic acid took up oxygen faster than did the unpasteurized, although without added ascorbic acid both juices took up oxygen at approximately the same rate. The same paper reveals the catalytic effect of iron and copper.

In 1947 Boyd and Peterson (6) commended de-aeration. They found that excess oxygen in canned orange juice may cause peeling of enamel in lined cans and promote corrosion in plain cans.

The merits of de-aeration as one of a chain of unit processes essential to the marketing of high quality orange and grapefruit juices was soon apparent and its application to-day is virtually universal.

In the processing of apple, grape and soft fruit juices its merits were not so readily recognized and its adoption in factories packing these juices had been limited. A review of experimental work on the processing of apple juice suggests that the value of de-aeration is influenced by (a) the other processes in the production chain, (b) the type of juice product, and (c) the method of packing.

In this country Charley (10, 11) commenced in 1932 a series of experiments on the preservation of juices, and the de-aeration of apple juice was investigated. In the U.S.A. in 1933, during investigation of pasteurization, Cruess and his associates (19) recommended de-aeration. Two years later, Tucker, Marsh and Cruess (65) suggested de-aeration by subjecting a batch of juice to a " high vacuum " of 28-29 inches mercury* for a period of 20 minutes.

Eight publications (5, 9, 10, 11, 32, 42, 43, 50) during the years 1937 and 1938 reveal the interest at that time. Pederson and Tressler (50) while advocating de-aeration of cloudy juices, were not convinced that any advantages were gained when packing clarified juices. However, in a paper published in 1943 (63) they recommended de-aeration for general processing.

Tucker, Marsh and Cruess (65) included de-aeration in their scheme for processing apple juice, and later Sipple, McDonnell and Lueck (55) claimed that de-aeration assisted flavour retention and the appearance of the final product. Marshall (44), however, contended it was not essential when packing canned apple juice.

Tempany (59), reviewing the processing of juices, commented on the advantages of de-aeration before cold storage or pasteurizing of natural juices.

There is no doubt that while flavour may suffer little change when packing natural strength apple juices in cans, the colour of the products may be influenced by de-aeration. If, however, it is intended to pack the finest quality juices obtainable by storing and blending, de-aeration immediately after extraction and prior to storage is most desirable. Experiments conducted by the A.P.V. Company, London, have indicated the changes that may occur in juice (stored at low temperature and under low pressure CO_2) that has not been subjected to de-aeration. Comparative samples, both stored under identical conditions that inhibited fermentation, revealed the depth of colour imparted by oxidative changes.

Although the application of this treatment is rapidly increasing, particularly in the citrus industry, there are but few published details concerning the physical methods adopted. Pulley and von Loesecke (52) have given the results of tests with various types of de-aerators operating under different pressures, but comparison of the results does not lead to definite conclusions, the efficiency of the de-aeration being dependent on four factors—pressure and temperature of the juice, the degree of dispersion, and the time factor.

To ensure complete elimination of oxygen some authorities (6, 55) suggested that " flashing " should be adopted, this being achieved by feeding the liquor to the vacuum chamber at a temperature some degrees (5° to 10° F.) higher than the saturation temperature equivalent to the absolute pressure. This method results in the liberation of water vapour ($\frac{1}{2}$ per cent. to 1 per cent.) which facilitates the complete removal of dissolved gases. However, the characteristics of most juices depend on volatile esters, aldehydes and sometimes oils in suspension, and there is little doubt that some of these substances will be lost by this method. The advantages gained by complete removal of dissolved gases can be questioned if other processes in the chain of production may later allow partial reabsorption of air.

It is recognized that " flashing " is not a severe treatment when compared with the process of de-oiling which, as now practised, involves flashing approximately 5 per cent. of the juice, but it must be remembered that this latter treatment is only practised primarily to eliminate oils from citrus juice.†

With the overall processing technique that is current to-day, there is little advantage in pre-heating the juice or its subjection to high vacua of less than 20 mm. mercury absolute. A feed temperature 10° to 15° F. below the equivalent saturation temperature in the vacuum chamber is not a serious disadvantage providing the absolute pressure is below 50 mm. and the apparatus is designed to disperse the juice as a spray or thin film. These conditions are revealed in Fig. 41, which is based on the vapour pressure characteristics of water. Theoretically de-aeration should be 100 per cent. effective when the feed temperature agrees with the saturation temperature equivalent to the absolute pressure in the vacuum vessel (Slope A). If the feed temperature is lower, some gas remains in the solution (Curves B, C and D),* while if it is higher then some juice will flash (slopes E, F and G). For example, with an operating pressure of 40 mm. mercury absolute (approximately 28·4 inches Hg vacuum) the diagram shows that the corresponding saturation temperature is 34° C. (93° F.). At this pressure good de-aeration can be achieved with temperatures of 70°-80° F. If the juice is preheated to 40° C. (104° F.) approximately 1 per cent. by weight of the feed will be vaporized. This fraction, containing many of the compounds responsible for the flavour, is a direct production loss, unless special and complicated refinements are introduced to effect its recovery.

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* At this time (1935) a vacuum higher than 25 mm. mercury absolute was seldom employed in the food industry. To-day there is need to rationalize the nomenclature due to the extension of vacuum processing. A reading of 28·5 inches mercury on a bourdon gauge may represent any process pressure between a few mm. and 50 mm. mercury according to the prevailing barometric pressure. It is therefore desirable that tests on vacuum plant should be made with absolute gauges and the expressions " high vacuum " and " low vacuum " should be abandoned since their interpretation varies from one application to another, and their significance is lost now that a wide range of low pressures are used in industry. It has been suggested (66) that any pressure from atmospheric down to 100 microns ($\frac{1}{10}$ mm. mercury) should be referred to as a low vacuum. While it is doubtful if this will be adopted for industrial purposes, it does reveal the need for revised and standardized nomenclature.

† See Editorial Note on p. 88.

Volatile substances, separated from the juice by evaporation, can be recovered, but experiments with citrus juices have shown that most of the original flavour characteristics have then been lost. Some water and volatiles will be lost when the juice is fed to the de-aeration chamber at a temperature 5°-10° F. below the saturation temperature, but this is unavoidable due to the inherent vapour pressure characteristics. Providing air leakage into the chamber is negligible, the loss will not be serious.

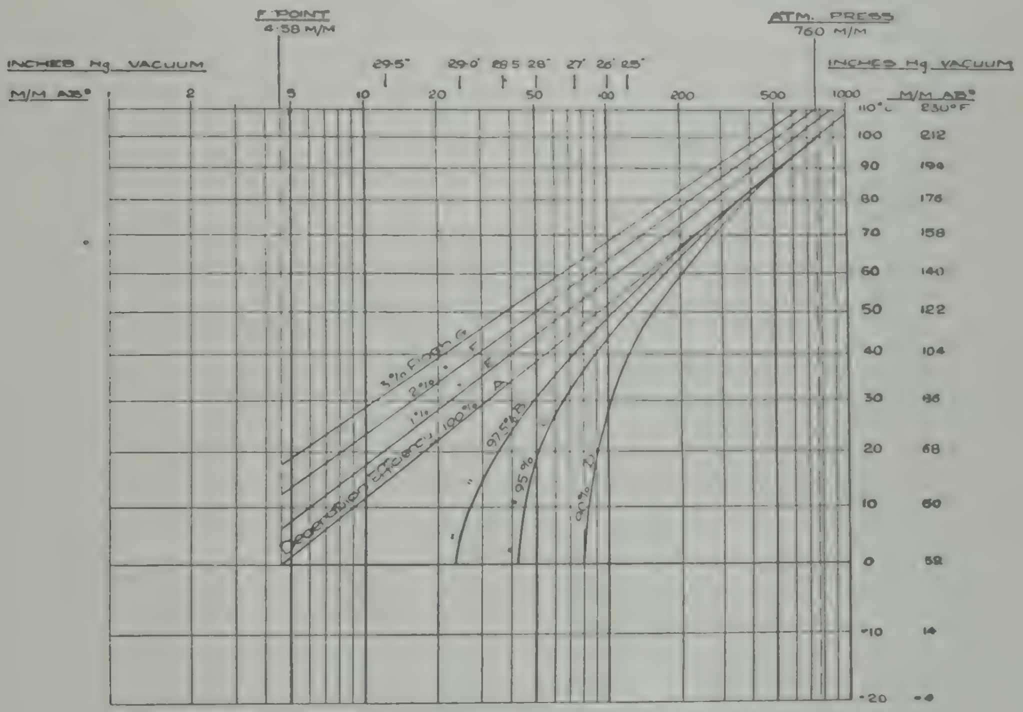

FIG. 41.

Influence of temperature and pressure in de-aerator.

A diagram based on the vapour pressures of water is not accurate for juices, but the error is not appreciable, the curves and slopes indicating the general influence of employing absolute pressures below 5 inches mercury (25 inches of vacuum).

De-aeration equipment

For commercial processing the available types can be grouped into three divisions:

(a) Centrifugal machines as originally suggested by Pulley (see page 70).

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[*] The percentage figures quoted in curves A to D refer to the theoretical de-aeration achieved when processing juice fully saturated with dissolved air at atmospheric pressure.

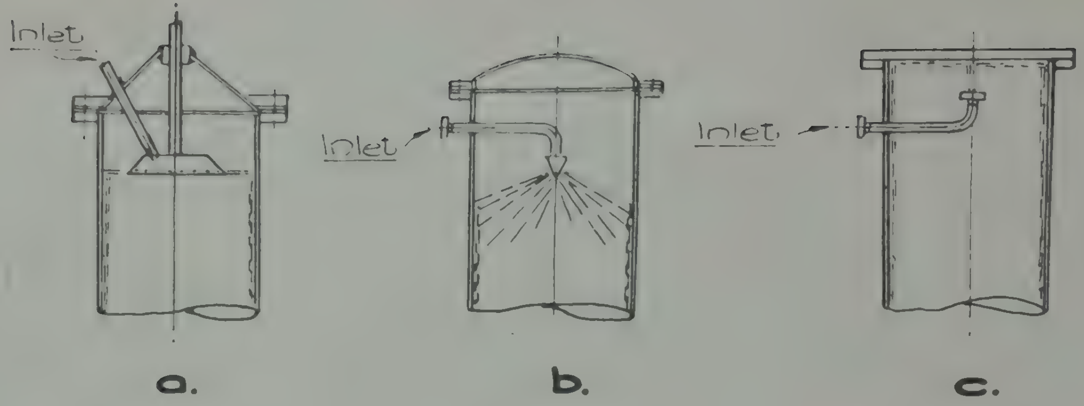

FIG. 42.
Types of de-aerator, showing methods of juice dispersal.

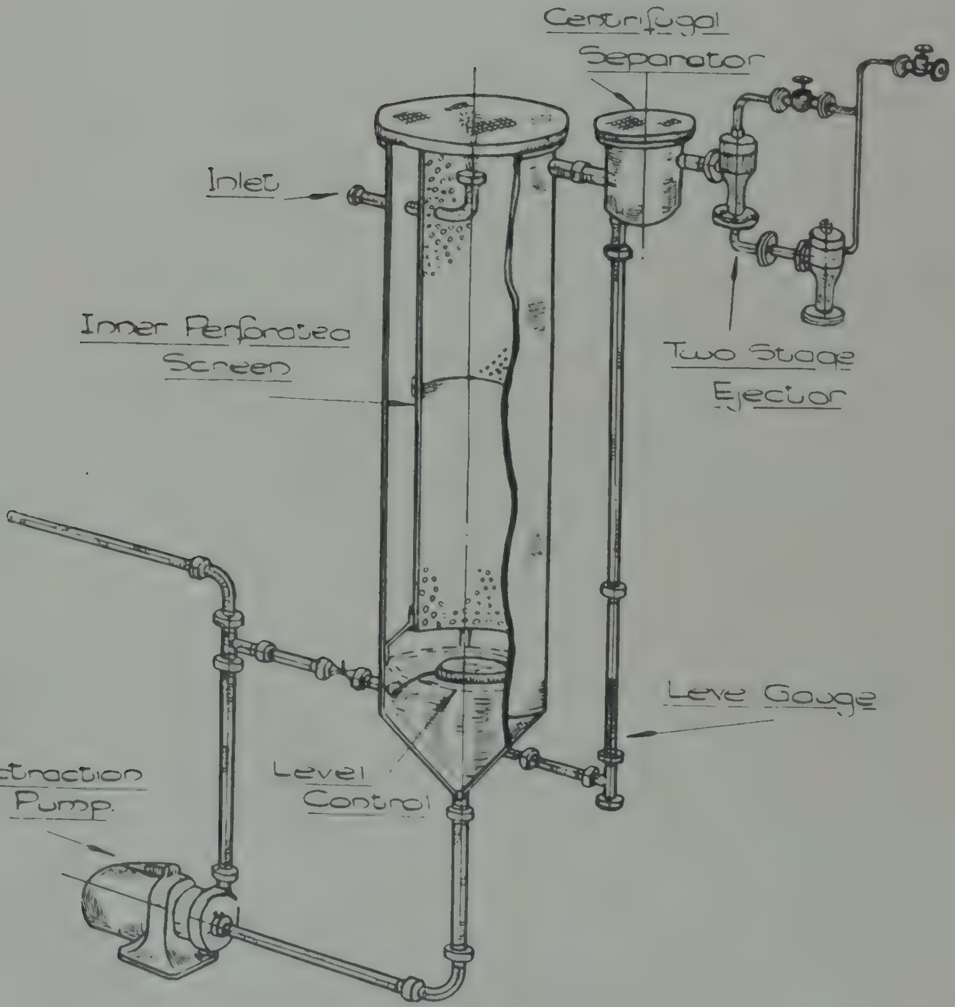

FIG. 43.
Arrangement of de-aerator.

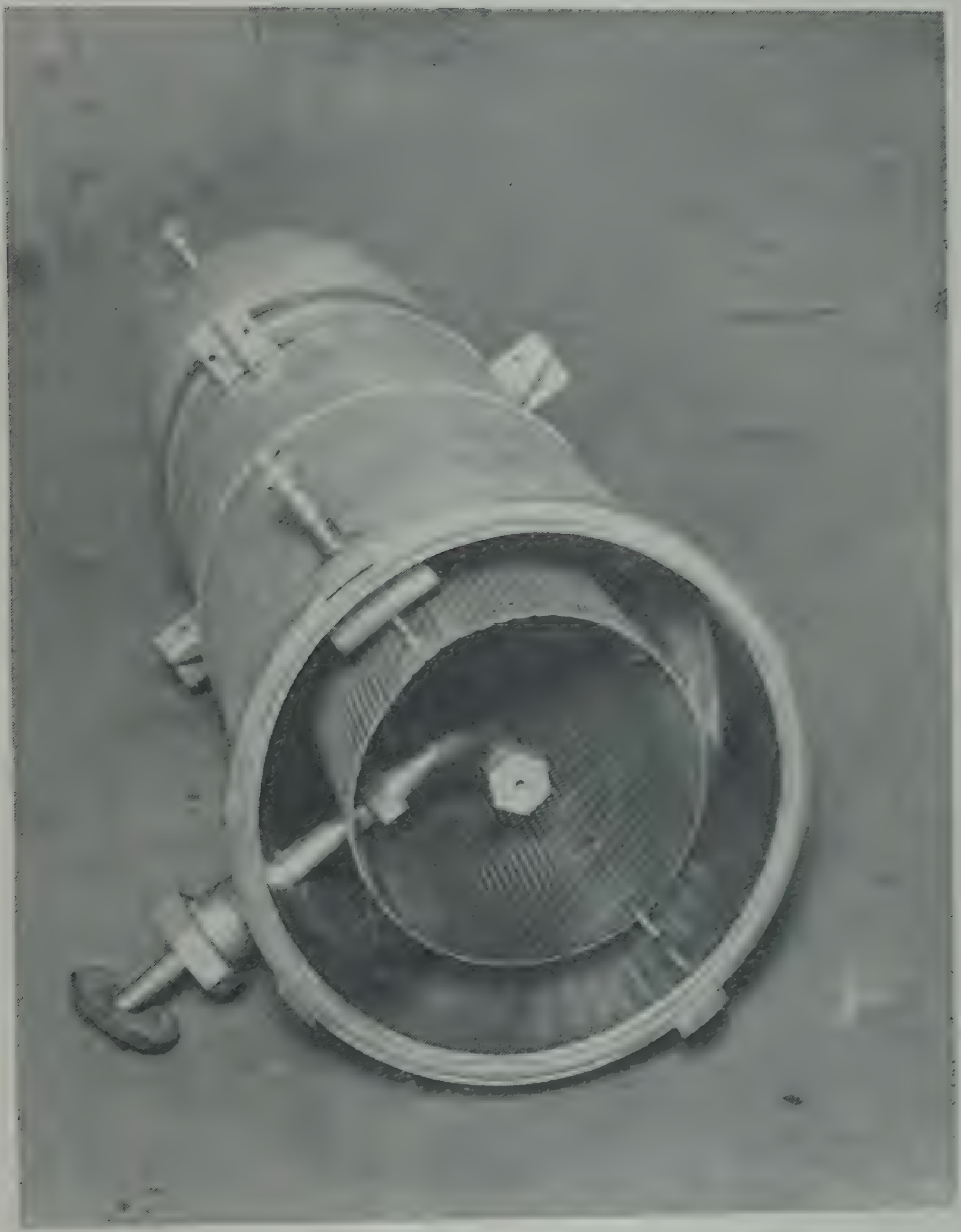

FIG. 44
Top view of APV film type de-aerator chamber.

(b) Spray type chambers in which the juice is finely dispersed into minute droplets.

(c) Film type units where dispersion of the juice is obtained by spreading a jet into a number of thin layers.

The diagrams in Fig. 42 illustrate the principles of these three types.

In each case, a vessel or chamber is employed into which the juice is injected and from which the gases are removed at the top and juice extracted from the base.

A plant (24) designed and constructed in England by the A.P.V. Company Ltd., and suitable for the processing of natural strength juices is described below (Figs. 43 and 44). It is essentially a film type de-aerator suitable for treating both clear and cloudy juices and is now employed extensively for the de-aeration of citrus juices, some grades of which contain suspended pulp and fruit cells. The juice is drawn through a single jet and impinging on the glass cover at high velocity is dispersed radially. Lightly pressing against the cover is a screen which traps more than half of the juice, the remainder passing through perforations to the wall of the vessel. The juice then flows down the three surfaces, the inner and outer surface of the perforated screen and inner wall of the vacuum chamber. At the bottom it is extracted by a centrifugal pump (Figs. 45 and 46) the suction to which is kept sealed, maintaining a certain level of juice in the chamber. This volume of juice is maintained by circulating a small side-stream from the pump discharge through a float-operated valve, while the overall discharge from the pump is controlled through wide limits by operating a control cock above the outlet port. It is therefore possible to throttle the pump discharge to approximately 500 gallons per hour, when operating the plant at about 400 gallons per hour, the excess being returned to the vessel, maintaining a fairly constant level in the vessel and compensating automatically for small variations in the rate of feed. It has been found on some installations that the extraction of the juice from "low level" de-aerators has not always been successful. This trouble arises from cavitation in the pump and can be avoided by selection of a unit with a suitable design of suction branch

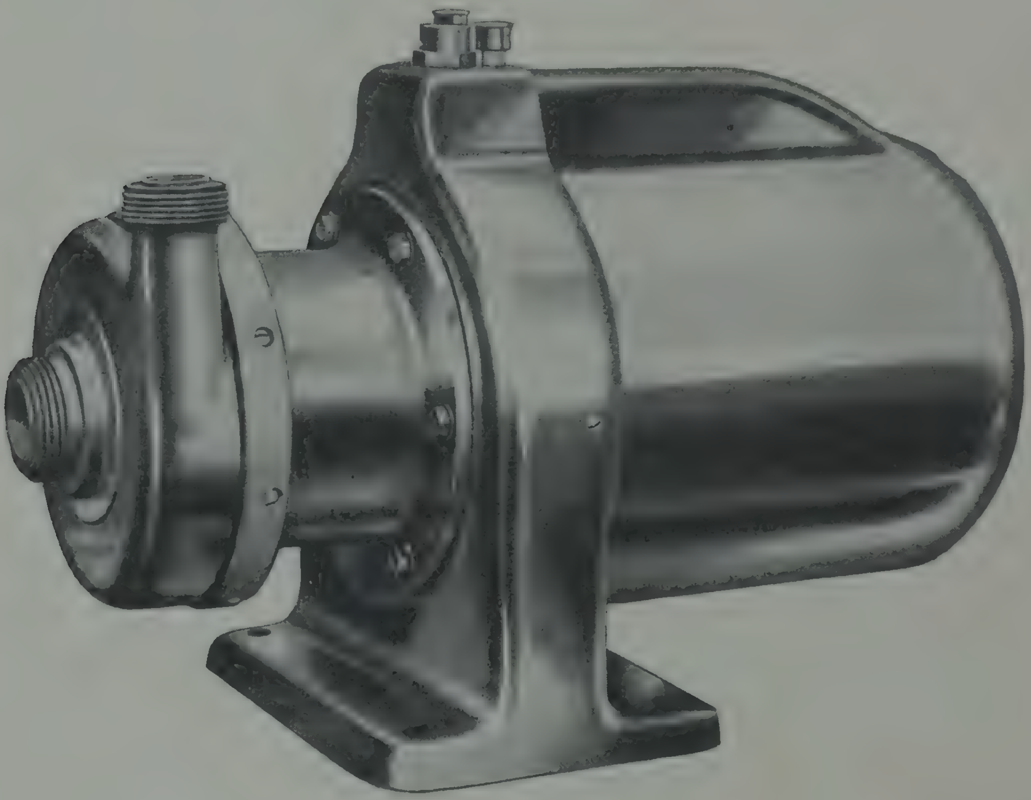

FIG. 45.

APV centrifugal pump for "non-viscous" juices.

and impeller characteristics. The gases liberated in the chamber are drawn from the top of the vessel, passing through a centrifugal separator and foam trap, and finally being discharged to atmosphere through a steam jet ejection pump. This pump is a two stage unit capable of maintaining an absolute pressure of 15 to 30 mm. mercury and does not necessitate the inclusion of an interstage condenser with its associated water seal or extraction pump.

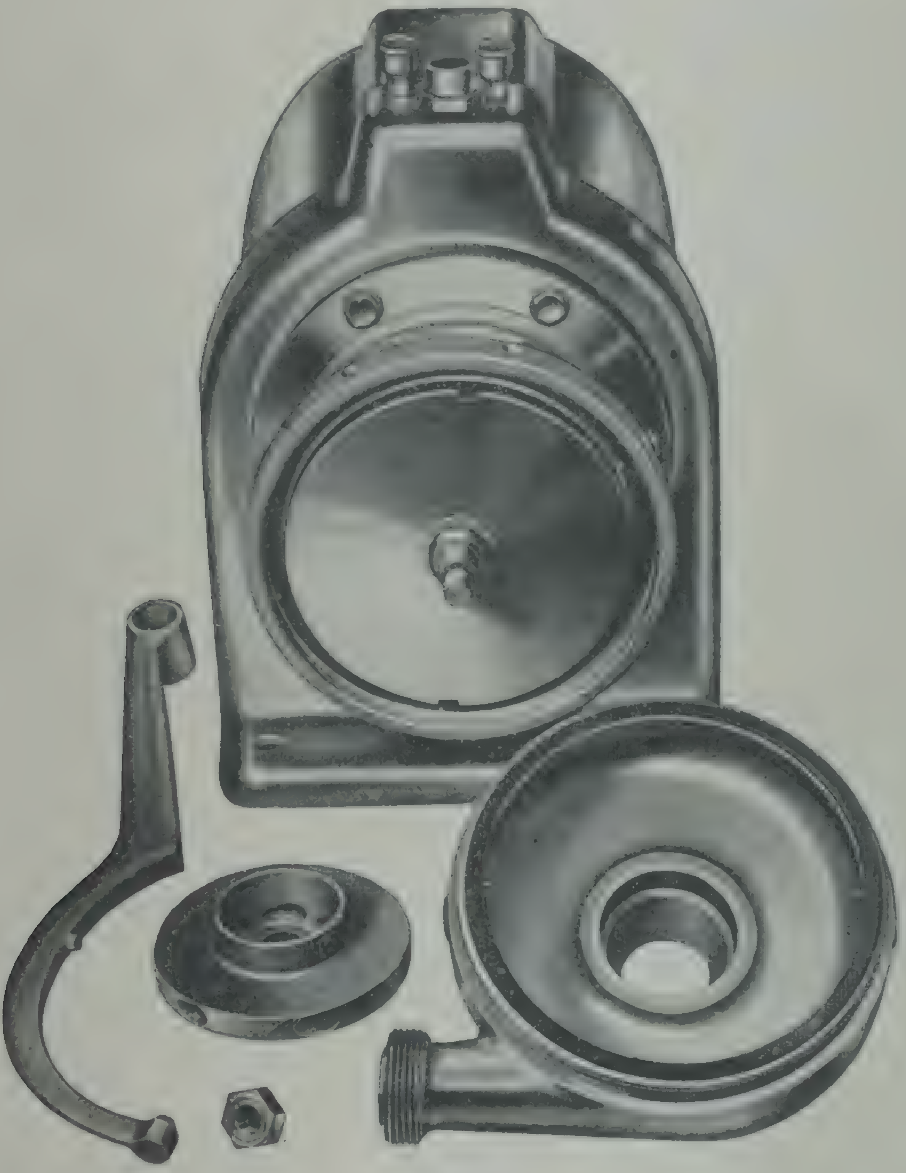

FIG. 46.

APV pump dismantled.

The average " hold up " time in the chamber is less than two minutes and it is possible to withdraw all the juice from the vessel at the end of a run by closing the cock in the sidestream connection.

The chamber and all accessories in contact with the juice are now made from stainless steel and the method of construction facilitates rapid dismantling for routine cleaning. The glass cover can be lifted off when the vacuum is released, and the jet assembly can be quickly detached and the perforated screen lifted out in two sections.

Determination of dissolved oxygen

The determination of gas and oxygen dissolved in juices has presented many problems and various methods have been employed, most of them having limited practical value.

Dissolved gases in water can be measured by the Winkler method of titration. This cannot be used for fruit juices owing to the presence of organic substances.

Gasometric methods have been devised; Clarke (15) describes an apparatus for determining the oxygen in canned juice. This method is mainly employed for testing packs immediately after filling to ensure that the dissolved oxygen is below a stated minimum. While serving as a routine test, the accuracy of the determination may be affected by oxygen consumed during filling and closing. It is suggested that this can be checked by determining the nitrogen content and multiplying by a correction factor, i.e. 0·2625. This factor, however, assumes that all gases are of atmospheric origin and does not allow for gases dissolved during filling.

Pulley and von Loesecke (52) carried out experiments with a modified Peterson (61) apparatus. This method takes approximately 90 minutes and Loeffler (38) revised the apparatus to reduce the time for a determination to 15 minutes.

The van Slyke (51) apparatus employed for the analysis of blood gases has been considered but is not extensively applied to fruit juices. It requires skilled handling and the juice must be free from CO_2.

It is in the processing of citrus juices that the residual oxygen content and its determination are important. In recent years attention has been given to polarographic methods. An apparatus is described by Lindquist (37) who employed a pressure of 0·8 volt for determinations on grapefruit juice. A similar procedure has recently been described and tested by Lewis and McKenzie (36) for oxygen determinations with orange juice, for which purpose they selected a pressure of 0·4 volt. In these two methods, the apparatus is calibrated against a standard method for fully saturated conditions. Galvanometer readings are taken for the extreme conditions of saturation with and without dissolved oxygen. This gas in a given sample is determined by the percentage saturation, which is estimated from a linear extrapolation of the extreme galvanometer readings.

Applied de-aeration

The influence of employing de-aeration as a unit process in the packing of juice products can be assessed from a summary of its effects.

(1) It will minimize losses of ascorbic acid, particularly if the juice is subsequently pasteurized.

(2) Oxidation of the juice constituents, such as oils, is limited, thus minimizing flavour changes.

(3) It is often beneficial when juices are to be packed in enamel-lined cans.

(4) Applied immediately after juice extraction it will limit the fixation of hydrogen as hydrogen peroxide.

(5) Occluded gases are removed from fruit pulp and cells, the separation of which on the surface of the juice will be limited.

(6) Foaming during filling into cans or bottles is virtually eliminated.

(7) De-aeration will retard the onset of fermentation on account of the attenuation of the oxygen content, which will have its natural inhibiting effect on yeast growth.

Finally, the value of de-aeration can only be decided by considering its influence in relation to all the other unit processes involved from the reception of the fruit to the packed product. Developments in the methods of de-aeration are in fact conditioned by the general methods of processing. If the juice is exposed to atmospheric conditions after de-aeration and before being sealed, oxygen is again absorbed, the extent depending on the time, temperature and degree of exposure. If processing includes thermal treatment in a closed circuit and packing and sealing is carried out within an inert gaseous system, the efficiency of de-aeration will be of relatively greater importance. If oils are incorporated in a juice and it is desired to reduce their content, a more severe technique is adopted by "flashing" the juice in the de-aeration chamber. When de-aeration is adopted before pasteurizing a juice that is to be concentrated, the advantages are limited to preventing ill-effects during heating and only a limited de-aeration is necessary—complete de-aeration occurring during concentration.

PASTEURIZATION

Modern dictionaries and works of reference define pasteurization as a heating process. While this is consistent with current practice many refer to temperature conditions that have, in industrial practice, been superseded. Recent experiments suggest that revision of terminology is necessary if the title pasteurization is to signify the " end " and not the " means ". Ball has recently described the treatment of milk with ultra-violet rays under the title " Cold Ray Pasteurization . . .". The terms pasteurization and sterilization, as they are employed in the food industry, are to some extent synonymous; while the former usually refers to the treatment of acid (and some non-acid) liquid products, the latter to solid food packs (usually non-acid and requiring more severe processing) there are exceptions which prevent precise definition. A broader definition that will include current practice and possible developments is suggested.

> " The treatment of *liquid* food products to ensure (*a*) The destruction of pathogenic organisms or (*b*) The destruction of micro-organisms and inactivation of enzymes to enable food to be preserved for a prolonged or infinite period."

More than one hundred years before the classic work of Louis Pasteur, methods of thermal treatment for the preservation of food were being tried. Many wrote of those experiments in the latter half of the eighteenth century. Nicholas Appert established the current methods of food preservation in 1804. Fifty years later, Pasteur discovered the fundamental reasons and provided the scientific answers to problems that for a century had eluded solution.

The treatment of fruit juice

Before describing various methods of treatment that are practised to-day, it is desirable to review the actual objectives in the processing of fruit juices. Yeasts, moulds and bacteria, together with chemically active substances, may be present in juice at various stages of extraction and processing. Moulds are the most active group since the environment is well suited to them, but the pasteurizing conditions now practised will ensure their elimination. Yeast cells will also be present, but they are more susceptible to heat and therefore thermal conditions which destroy moulds will normally be ample for yeasts. Mould and yeast spores, however, are more resistant and often survive heat treatment, but the subsequent development to the propagating condition seldom occurs. Bacteria seldom develop in acid juices and cause little concern to the packer. There are, however, exceptions to this generalization (4) and special sterilizing conditions are necessary with juices of pH higher than 4·5—these often being referred to as non-acid juices, although the pH is less than 7·0.

Present-day conditions used for the pasteurization of citrus juices have been primarily determined by the necessity for inactivating pectin enzymes. These enzymes are usually present in the original fruit, where they have a function in the changes in pectin during ripening. They may also be produced by micro-organisms that find ingress to the fruit or contaminate the juice after extraction. Pectin enzymes are also added during the processing of other fruit juices (see p. 152) and need to be removed by heat treatment before further processing.

The natural characteristics of citrus juice can only be retained by maintaining the cloudy state in which it is extracted. This cloud is stabilized primarily by pectins which are responsible for " binding " the cells in the ripening fruit. If the pectin is hydrolysed to pectic acid, this will coagulate and precipitate and thus the juice will clarify. This process will occur naturally due to the presence of pectin esterase which de-esterifies pectin to pectinic acids and pectic acid. It will be apparent that, if the cloudy nature of the juice is to be retained, the pectic enzymes must be inactivated.*

* See Chapter XI.

Enzyme systems are numerous and complex. Stephens (57) refers to two systems being responsible for cloud coagulation in orange juice, one with an optimum activity at 35° C., the other at a much lower temperature.

The destruction of moulds and yeasts infecting fruit juice and the inactivation of enzymes in citrus juice are essential if the natural process of change causing deterioration of the juice is to be minimized. To-day thermal treatment is practically universal and it is necessary to determine the optimum conditions; that is, the temperature to which the juice is to be subjected and the time relative thereto. The factors influencing these conditions include acidity of the juice, degree of infection, and to a limited extent the presence of suspended matter, pulp, etc. In commercial practice only the pH value may occasion an adjustment to the usual thermal treatment, a lower pH permitting processing temperatures to be reduced.

Thermal pasteurizing—by conduction

To differentiate between the early and current processing conditions three distinct methods can be classified.

Holding process—originally employed; after heating the juice it is retained at elevated temperatures (*ca.* 150° F.) for periods of 20-30 minutes.

H.T.S.T. process—" High temperature - short time." Rapid heating to 170° to 200° F. with a " holding time " of 15-60 secs. before cooling.

Flash process—Rapid heating to temperatures of 190°-250° F., followed immediately by some degree of cooling, the juice not being retained for any determinate period of time at the peak temperature.

The reason for the transition from low temperature holding systems to H.T.S.T. is clearly revealed when the relative influence of time and temperature on organisms and on flavour changes is considered.

The thermal death rate—T.D.R.—of organisms increases roughly ten times for an increase of 10° C. in the processing temperature; alternatively, for a given T.D.R. the time of exposure can be reduced to about one tenth if the temperature is increased 10° C. The reaction speed that is responsible for flavour changes is accelerated only two to three times by a similar rise in temperature. Thus for a 10° C. rise in processing temperature the time factor for sterilizing is reduced ten-fold and the nett influence on the flavour by this combination of time and temperature is less than one third.

This generalization is applicable at constant temperature, but in practice many complicating factors are present and its significance when comparing H.T.S.T. and flash treatment is not completely revealed owing to the rapidly changing temperature during heating and cooling.

Should the H.T.S.T. system be distinguished from the " flash " process? There are two objects in suggesting this division: (*a*) the correlation of terminology in food industry generally* and (*b*) to ensure correct interpretation of process conditions when these are given as time and temperature.

Operating conditions are seldom clearly and precisely defined. In the H.T.S.T. system it is customary to quote the maximum temperature to which the juice is heated and the time it is retained or held in the apparatus at this temperature before cooling. The time of heating up to this temperature is rarely quoted and is relatively unimportant if rapid heating is practised. With flash treatment the time factor is usually given for the heating period. Any retention of the juice at peak temperature is important; if the juice is passed through a pipe to a filling machine, the hold-up at elevated temperature—even though slightly cooled below peak temperature—is the principal factor in flavour changes. While current methods of filling cans with hot juice and holding to sterilize the closure before cooling are practised, the value of extremely rapid pasteurization is in question. Process conditions should therefore be quoted in greater detail if the overall thermal influence is to be compared and assessed.

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* Milk pasteurization as now practised is known as the H.T.S.T. process—heating to 160°-162·5° F., holding for 15 seconds and then cooling.

In 1938 Ball (2) read a paper in which the term " flash " pasteurization was expressed, but after discussion this was changed to " high short " when publishing. The fact that the term " flash " has prevailed and is now rooted in industrial terminology supports the idea that some definition of process boundaries is to be desired.

In the laboratory, where rates of flow are limited, the coiled tube heater is widely used for experiments with continuous flow of liquid foods. When processing on a commercial scale, the plate type heat exchanger is employed owing to its inherent versatility ; it can be adapted for manifold duties, the contact surfaces are accessible for cleaning, and the plates can be rearranged to accommodate changes in process conditions or rate of flow.

A typical plate arrangement in a heat exchanger frame is shown in Fig. 47. Diagram (a) illustrates the flow of juice when heating from cold, pasteurizing with or without holding time at peak temperature, followed by slight cooling to a suitable filling temperature. Diagram (b) refers to the same machine with the connections rearranged to enable juice to be heated from cold to pasteurizing temperature, holding, and then cooling, first by regeneration* with incoming juice and finally with cooling medium, down to atmospheric or lower temperatures for bulk storage. Heating is usually done with hot water circulation and automatic control of pasteurizing temperature is achieved by control of the steam input to the hot water circulation system. The maximum temperature of the heating medium is usually no more than 3° to 5° C. higher than the pasteurizing temperature, although in certain cases where higher differentials can be employed the platage in the heat exchanger can be reduced. The machine referred to above is shown in Fig. 48 ; the " follower " is withdrawn to reveal the design of the plate and the access for cleaning. A larger machine is shown in Fig. 49, the model illustrated being suitable for straight heating of clarified juice at rates of flow approximately 1,000-1,500 gallons per hour.

Combined unit for de-aeration and pasteurization

Since de-aeration usually immediately precedes pasteurization it is convenient to unite the equipment for these operations into a single unit. The combined installation shown in Fig. 50 was installed for Messrs. W. J. Bush & Co. Ltd., London, E.8. The apparatus includes a feed tank with slow speed agitator, and product tank suitable for sterilization.

In the illustration can also be observed the hot water circulating equipment (centre background). Provision is made for various combinations of heating and cooling duties. In front of the structure is the insulated holding panel ; the capacity of the tubes in circuit can be varied for H.T.S.T. operation or they can be isolated for flash pasteurization.

Twentieth-century developments

McDermott (48) and Cruess (17) both contributed to the effective use of thermal pasteurizing for preserving citrus fruit juices. Cruess in 1914 made the critical observation that orange juice remained cloudy when pasteurized at a temperature of 185° F. Previously, pasteurization by holding at low temperature (150° F. for 30 minutes) preserved the juice but the products soon changed in character by precipitation of the cloud and the deposition of suspended matter in the base of the container. Whether the importance of this discovery and the recommendations of Chase (13) in 1920 were fully recognized is doubtful, since it was not until 1934 that the commercial processing of orange juice received the impetus that has carried its production to the present level in the U.S.A.

Flash pasteurization was studied in many laboratories between 1930 and 1940. Experiments by Mottern, von Loesecke and Pulley (39, 46) and papers by Joslyn and Marsh in 1933 (28) and 1934 (29) indicate the advantages of " flash " treatment and reveal the effect of processing conditions in relation to the inactivation of enzymes in orange juice.

In 1937 Heid and Scott (22, 23) carried out extensive experiments with flattened tube coil heaters. In 1940 Joslyn and Sedky (33) suggested higher temperatures were necessary

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* The regenerative circuit employed when the juice is pasteurized and cooled for storage enables a saving of steam up to 80% of the quantity necessary for a straight heating duty.

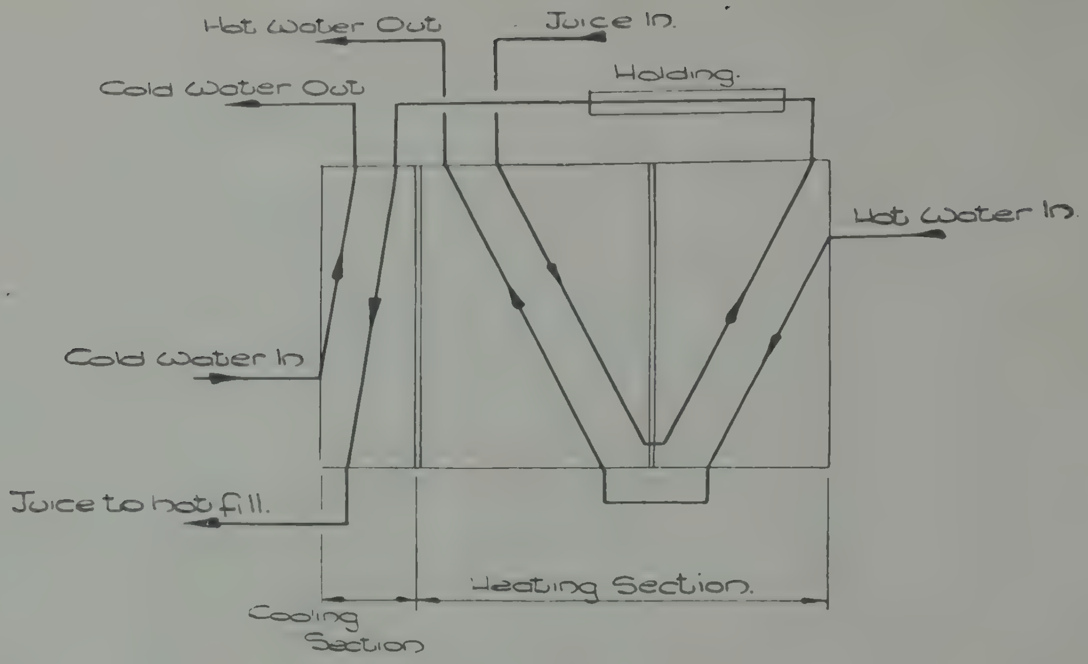

Diagram (a.)

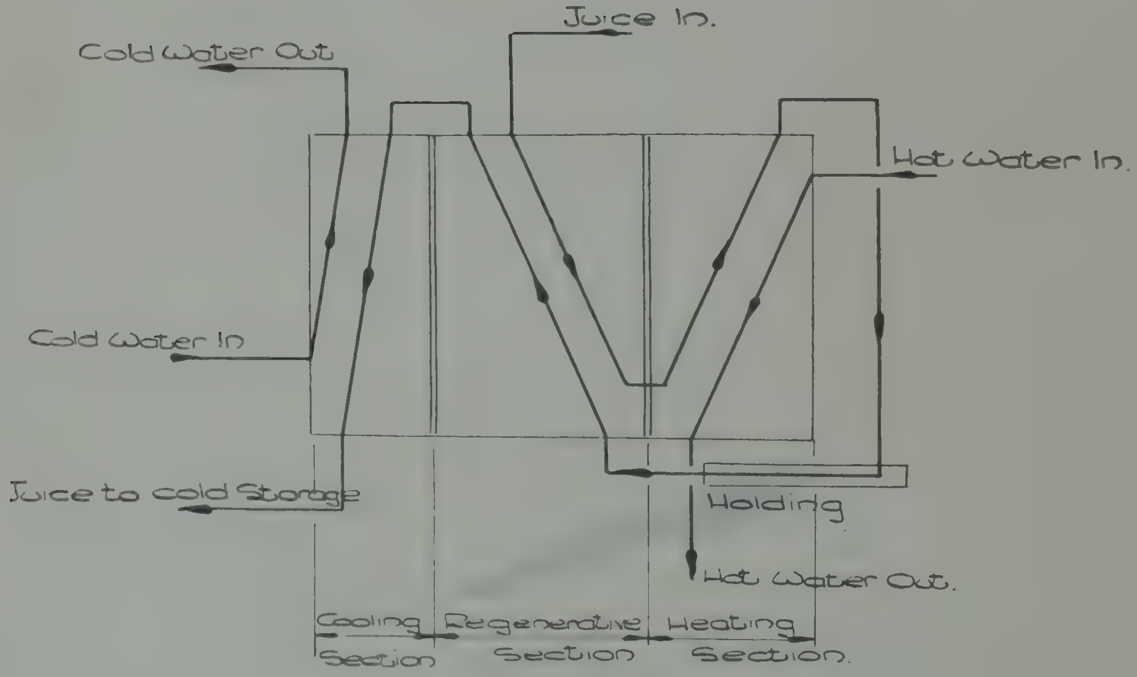

Diagram (b)

Fig. 47.
Typical plate type pasteurizing circuits.

to ensure inactivation of enzymes and the U.S. Department of Agriculture (14) published a circular in which the following pasteurizing conditions were recommended for citrus juices.

> "The temperature should not be higher than 205° F. nor lower than 199° F. The flow of juice should be so regulated that it is subject to this temperature for not less than 5 and not more than 10 secs. The juice is cooled to 170°-180° F. before it is put into containers."

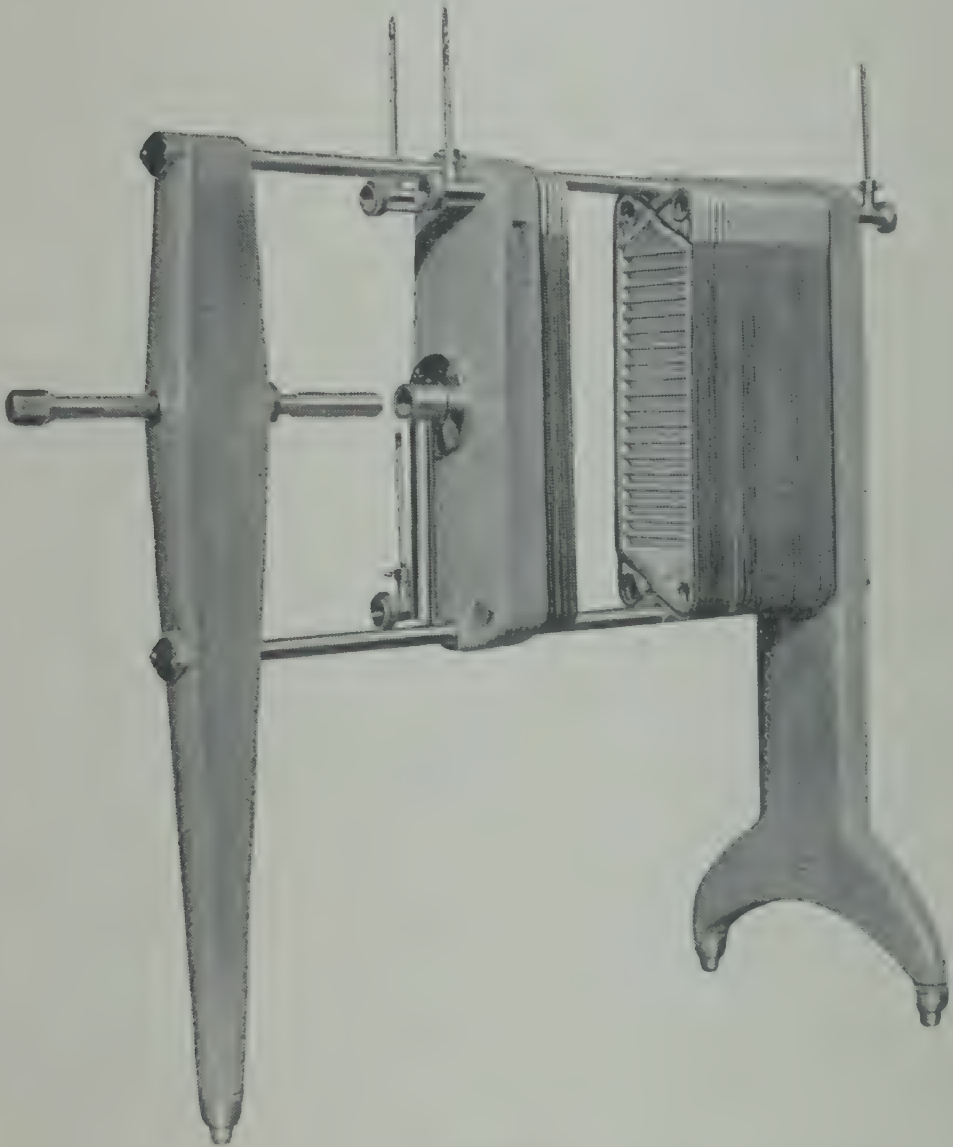

Fig. 48.

H.T.S.T. pasteurizer for fruit juices (with "follower" withdrawn).

Boyd and Peterson (6) in 1945 reviewed orange juice packing. The relative merits of pasteurizing conditions and methods of filling and closing were revealed. It was claimed that with cold filling, flash treatment with rapid heating to 225° F. and rapid cooling to 100° F. had no effect on flavour. Studies of the treatment of apple and other juices have been made concurrent with those relating to citrus juices.

In Europe, where the finest apple juices are prepared by judicious blending and storage after extraction, packing may be preceded either by flash pasteurizing or sterile filtration. In the U.S.A., where blending is achieved with whole fruit and storage of the juice is not extensively practised, pasteurizing is widely adopted. Tucker, Marsh and Cruess (65) recommended

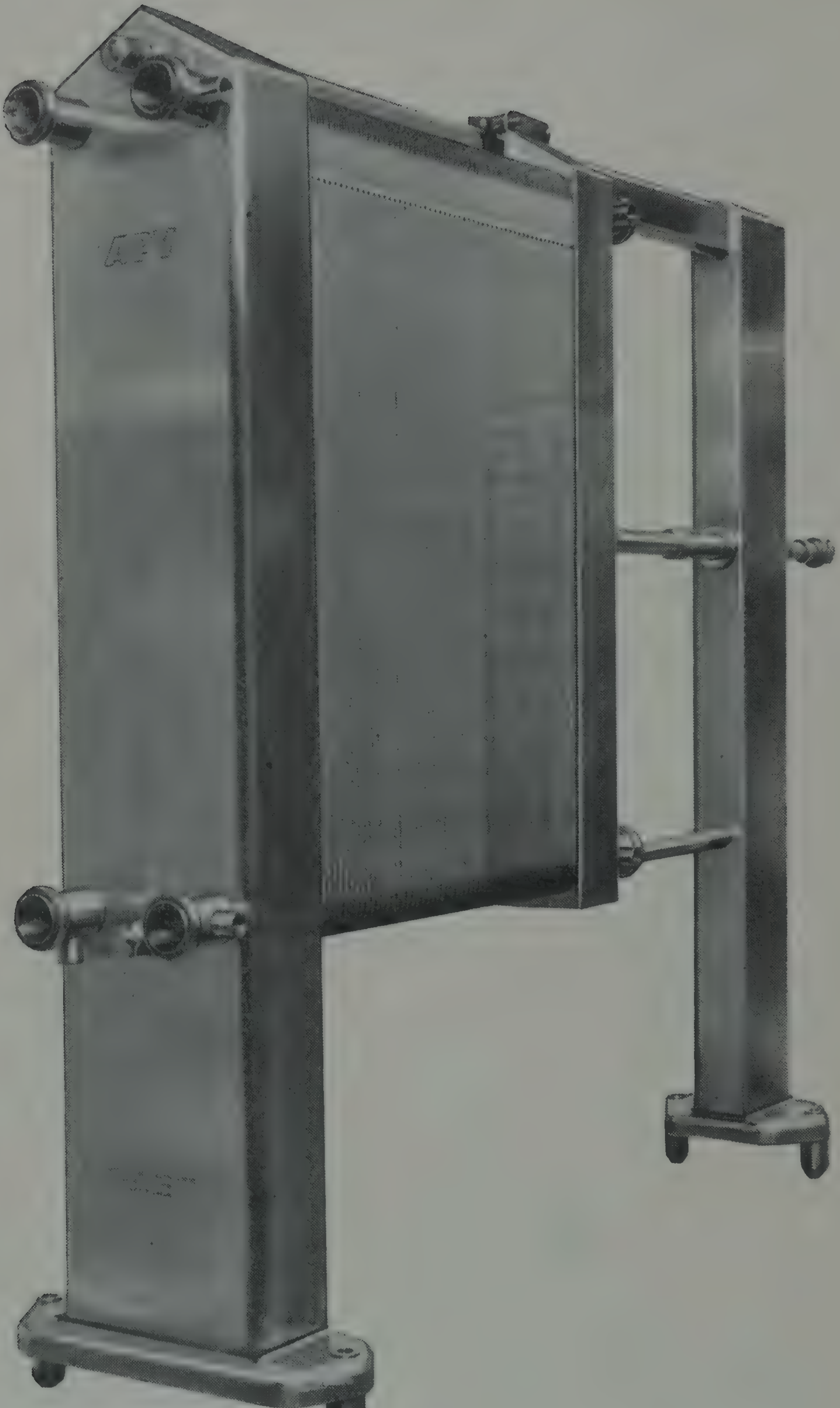

FIG. 49.
Large-sized H.T.S.T. pasteurizer.

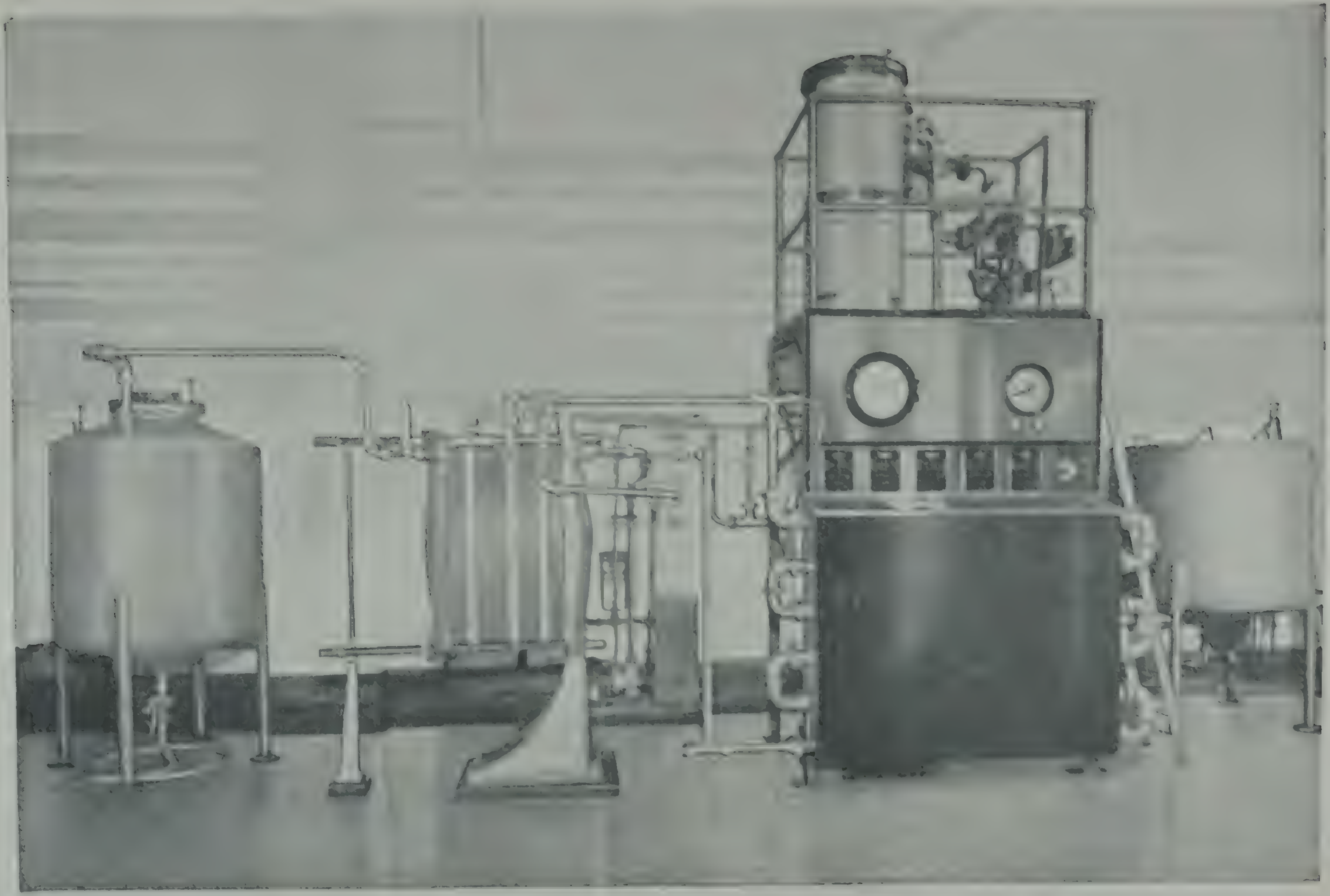

FIG. 50.
Combined de-aerator and H.T.S.T. pasteurizer for fruit juices.

flash pasteurizing at 185° F. for 30-60 seconds ; Celmer and Cruess (9) suggested 185° F. ; Pederson and Tressler in 1938 (50) preferred a lower temperature, 170° F. maximum when heating in one minute ; Charley and Sills (11) during investigations in 1938 conducted consumer acceptance tests in which juice pasteurized at 185° F. held for 30 seconds and filled at 160° F. was preferred. Seldom has the hydrogen ion concentration been quoted and this may be a factor in the selection of temperature. Most of the experimental work up to this time was done with a heating time of 30-60 seconds. Marshall (44) in 1941, using a flattened tube coil, recommended 170° F. for commercial processing. The heating time was only 2 to 5 seconds ; however, since the juice was filled at this temperature and the container then sealed and held for 30 seconds before being cooled, the short time of heating is relatively unimportant.

The above notes indicate experimental developments in the processing of orange and apple juices, these being typical of citrus and non-citrus juices. The processing of other juices has been studied with similar apparatus to reveal the optimum conditions for sterilization with minimum flavour change.

Thermal processing *as originally practised* gave rise to cooked flavours and these were not desired or acceptable in juices which were customarily consumed as fresh fruits. Various methods of processing have been suggested and adopted as alternatives to thermal treatment by conductance. Brandes, while not specifically referring to the processing of juices, submitted a paper on sterilization by oligo-dynamic methods—the destruction of organisms by low concentrations of metallic ions at normal temperature, notably silver. Mehlitz (45) has presented data on the Electro-Katadyn process based on the same principles. Another method combining thermal treatment and the oligo-dynamic principle is the Matzka process. Other possible methods include the subjection of juice to pressure (25), ultra-sonic vibrations, electric heating and high-frequency radiations. The use of ultra-violet rays has for long been of interest and its application, particularly to the pasteurization of milk, has been recently developed in Germany (3).

These methods have not yet been widely adopted and thermal treatment remains the principal method of pasteurizing.

Electric heating and radiant pasteurizing

Progress in the use of electric heating has been slow, primarily due to economic considerations, but recent developments indicate that the results have not been entirely negative and may eventually lead to the establishment of commercial processes. Therefore a review of processes employing electric power as the input energy resulting in either thermal or radiant pasteurizing is of value.

Dividing the processes into broad categories we have—

(1) Alternating current of frequency 50-50,000 cycles/second.
(2) Alternating current of higher (radio) frequencies. (10-3,000 megacycles/second.)
(3) U.V. radiations.
(4) Röntgen rays and Beta particles (cathode rays).

(1) *Heating with electric current*

This method of heating fruit juices has not been widely adopted for commercial processing. In Germany, according to L. B. Howard (26), Engelhardt has devised and employs an electric heater for pasteurizing clarified fruit juice. The apparatus comprises a platinum-lined tube housing a central platinum-coated rod, this and the tube being insulated from each other and connected to a source of electric current. The applied potential is 220 volts, frequency 70 cycles, and the current is 100 amperes. The unit is rated at 400 litres per hour, heating this quantity to 68° C. The retention time in the heater is reported as being 10 seconds, but from the available data this is approximately 30 seconds when operating at the above rate.

(2) *High (radio) frequencies (dielectric and induction heating)*

The interest in the application of radio frequency radiations for food processing is constantly increasing and data are steadily accumulating from which both the possibilities and limitations are being determined. Hartshorn* and Kinn (35) have given a review of radio frequency heating in which the principles of dielectric and induction heating are clearly described.

Yang et al. (68) have published the results of experiments in the pasteurization of wine using dielectric heating and frequencies of 26-34 megacycles. They indicate that pasteurization was satisfactory when subjecting a continuous flow of wine to these radiations for 4 seconds, the temperature rising from cold (70° F.) to 130° F. Conventional water bath pasteurization (thermal convection and conduction) required holding for 30 minutes at 140° F. or " flash " pasteurizing heating to 180° F. in 60 seconds. Few tests on fruit juices have been conducted and little data is available showing the influence on juice enzymes.

It has been stated by Sherman (53) that the current of these frequencies has no specific germicidal influence.

Comparative experiments conducted by the A.P.V. Co. on the pasteurization of beer by radio frequencies (dielectric heating) and by thermal conduction have revealed no significant difference in the time—temperature relationship. The beer was heated by the application of radio frequency (18 megacycles) and the total thermal processing necessary for a given reduction in the yeast count was the same as that required by conventional methods. These results suggest that the frequencies employed had no specific germicidal effect to augment the destructive influence of temperature.

If destruction is effected principally by thermal action the use of radio frequencies in the food industry will be confined mainly to the processing of solid foods. Thermal pasteurization of fruit juices by convection and conduction can be carried out at such a speed and with such limited effect on flavour that it is only likely to be superseded by a cold process.

There is, however, one interesting variant in the use of radio frequencies that merits reference here. Nyrop† working at the Niro Laboratum, Copenhagen, has reported on the biological effects of intermittent H.F. pulses. Bacteria have been effectively destroyed at low temperatures (relative to those necessary for " thermal " destruction) by subjecting the organisms to intermittent current discharges of 20 megacycles frequency. The pulse rate was 10-100 Kilocycles and " off-on " time ratio between 3 and 20.

For example, if the off-on time ratio was 9 and the " pulse rate " was 100,000 per second then the organisms were subjected to a pulse of 20 alternations of current in one millionth of a second, followed by an off or " break " period of time equivalent to 180 alternations, the pulse " on-off " cycle being completed in 100,000th of a second.

It is claimed that milk treated by this method for periods of approximately 1-2 seconds at low temperature acidified no more quickly than if it had been heat treated at 75° C. for 30 minutes.

(3) *Ultra-violet radiant treatment*

From the interest now apparent and the results published concerning the sterilizing of various liquids, the use of U.V. radiations is technically feasible and if practical designs can be developed for economic operation, this method may eventually be employed in the treatment of fruit juices. To conceive both the possibilities and the practical limitations, notes on fundamental data are printed below.

The bactericidal influence of U.V. radiations is well established, the effective band lying between wavelengths of 2,000 and 3,000 Ångström units. The useful band is much narrower—approximately between 2,500 and 2,700 Å, the peak occurring at 2,537 Å, this monochromatic radiation being generously liberated by a low pressure mercury arc. The utilization of this source of germicidal energy—which is easily generated—is primarily determined by the absorption, transmission and reflection characteristics of the juice to be treated and the materials of construction employed in a suitable apparatus. Luckiesh (40) has published data very useful for a study of the problems and it is from his book that the information given below has been obtained.

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* " Radio Frequency Heating." *Nature*, **157**: 607. 1946.

† A specific effect of H.F. electric currents on biological objects—Communication. *Nature*, **157**: 51, 1946.

Low pressure mercury arc tubes are now available; a 36″ × 1″ tube of 30 watts has an output of germicidal energy of 7·2 watts. The characteristics of the glass envelope are influenced strongly by traces of impurities and by thickness; minute traces of iron, 1 p.p.m., will seriously reduce the transmission and the thickness occasions a proportional loss by absorption. Many grades of glass are now available having excellent characteristics for the transmission of the desired wave bands with sharp cut-off of higher frequencies, which are almost completely absorbed. This cut-off is important in germicidal lamps because of the undesirable influence of radiations of length *ca.* 1,850 Å, which are responsible for ozone formation. It has been considered that this is one of the factors that has occasionally caused "tainting" of milk after U.V. treatment.

The next problem is to transmit the radiations to the juice so as to subject all the juice to an intensity sufficient to destroy organisms and enzymes by absorption and yet to avoid losses by absorption in the apparatus. The transmission of U.V. rays through many liquids is limited to thin films, water being an exception and of special interest since the influence of impurities is clearly revealed. Luckiesh gives the following data:

Distilled water	90 per cent. of incident radiations absorbed in depth of	115″
Town water (typical sample)	,, ,, ,, ,, ,,	12″
Milk	,, ,, ,, ,, ,,	0·003″
Apple juice (canned) ..	,, ,, ,, ,, ,,	0·05″

It is apparent that if the layer of apple juice subjected to radiation is thicker than *ca.* 1·0 mm., radiations will not penetrate and effective sterilizing will only be achieved by turbulent flow and extended time of exposure. Another example is of interest. Milk* has been subjected to U.V. treatment by passage through quartz tubing of 10 mm. diameter. Since the penetration of milk for 90 per cent. absorption is limited to *ca.* 0·003″ (0·075 mm.) film thickness, the volume exposed to effective† radiations is only about 3 per cent. of the tube volume—thus turbulent flow is essential and the time of exposure approximately thirty times that necessary if penetration were 5·0 mm. instead of 0·075 mm.

The apparatus employed was rated at 400 litres per section, giving an overall exposure time of approximately 60/70 seconds. If the effective penetration and tube size are taken as quoted above, then the "effective exposure time" is $\frac{60}{30}$ or 2 seconds.

It will thus be apparent that with liquids having a high absorption the processing of commercial quantities involves a large installation and the nature of this apparatus as now visualized requires skilled and constant attention.

The choice of materials to contain the juice is equally critical. If the apparatus is designed for the rays to pass through a retaining wall then a very high transmission factor is essential and material similar to the generator tube is desirable while the final barrier to residual radiation should have a high reflective value such as aluminium (approximately 85 per cent. of incident radiation reflected).

Another consideration is the temperature of the generating tube, for the intensity of effective radiations falls as the temperature is reduced. Luckiesh (40) referring to the work of Forsythe, Adams and Barnes states that maximum efficiency is obtained with the tube at a temperature of 40° C., the efficiency falling to about one half at 20° C. If a design were developed using submerged tubes this factor alone would theoretically double the time of exposure and hence double the size of apparatus when treating cold juices. The apparatus at Hansa Meieri, Lübeck, built by Siemens-Schuckertwerke, Berlin, for processing milk, operates above 30° C. for this reason.

The commercial use of U.V. rays for processing milk is still a subject of discussion, but when considering fruit juices the present high value of the pack and the possibility of being able to process at lower temperatures suggest that their application merits continued study. Here again each type of juice has to be given individual consideration. Cloudy juices with

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* Installation at the Hansa Meieri Facherberger Allee, Lübeck, Germany, details of which have been reported by Taylor, Coop and Smith (58), Kertesz (34) and Ball (3).

† There is obviously no precise effective depth or thickness. Effective exposure depth is assumed at 90% absorption.

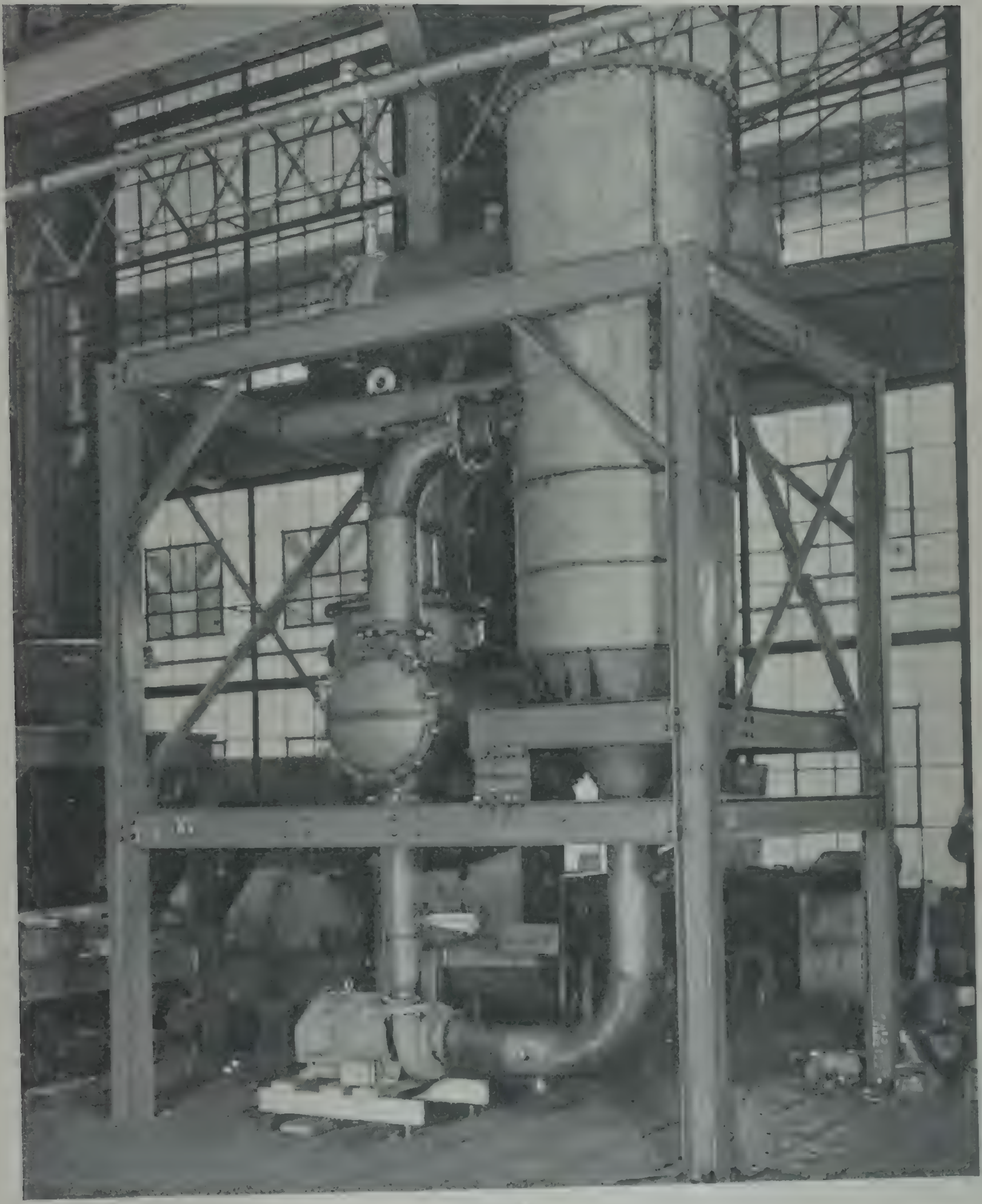

FIG. 51.
Buflovak de-aerator and de-oiler for citrus juices.

suspended solids will present greater difficulties than apple juice which, from the available data previously referred to, requires only about one twentieth the exposure time required by milk for a given degree of exposure and flow rate.

(4) *Röntgen rays and Beta particles (cathode rays)*

The practical use of these radiations in the food industry is still confined to academic studies and few data are available concerning their effect on fruit juices. The biological effects of these radiations has been studied by Dunn and others [J. appl. Physics, **19** : 7, 604, 1948]. Brasch and Huber (8) have carried out tests with an apparatus named a Capacitron which generates electron impulses at a potential of $3 \cdot 5 \times 10^6$ volts and current of 30×10^3 amperes, the impulse ranging from 10^{-4} to 10^{-7} second, usually one millionth of a second. Destruction of micro-organisms is achieved with one or more impulses. Enzymes, particularly oxidases, require more severe treatment. It is stated that the preservation of milk without change of taste is very difficult, but was achieved after de-aeration and irradiation at low temperature ($-30°$ C.). Jackson (27) refers to experiments being conducted at the Department of Food Technology, Massachusetts. His review of the use of high frequencies and germicidal rays ends with this paragraph :

> "The magnitude and diversity of the problems involved would make it appear that the studies of preservation of food by irradiation without heat are still largely in the realm of pure science and may best be handled by academic institutions."

EDITORIAL NOTE

De-aeration

The Buflovak de-aerator and de-oiler may be quoted as an example of an American machine which simultaneously removes dissolved gases and excess oils from citrus juices. The use of such a plant enables a more thorough initial extraction of juice to be effected from the fruit, for the excess oils that are removed from the fruit can later be taken off together with the dissolved gases. Fig. 51 shows a Buflovak de-oiler and de-aerator.

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CHAPTER V

CONCENTRATION OF FRUIT JUICES

The importance of developing processes for the concentration of fruit juices that impair the natural flavour of the juice to the absolute minimum has been appreciated by chemical engineers for the past two decades. The urge to solve the problem of flavour depreciation and loss of aroma became intensified during the last war, however, on account of the increased attention paid to fruit juices and the desire of various Governments to transport juices for their forces in all theatres of war, entailing vast mileages and enormous quantities of materials. As an additional example of this may be cited the almost complete switch-over of imported citrus juices in the United Kingdom during the war years from straight, unconcentrated juices to concentrates of 4 : 1 to 7 : 1 strength. The entire citrus squash industry was confronted with the problem of using a new type of fruit base and although at the commencement of the war the quality of the concentrates left much to be desired, very marked improvements were effected in the various citrus producing areas, where necessarily the fruit juice processing plants must be situated. Of even greater importance was the adoption by the British Ministry of Food of a canned orange juice concentrate for use as a supplementary source of vitamin C for distribution to children up to the age of five years. This ambitious scheme, which has apparently become a permanent institution, calls for very large bulks of canned orange juice with a guaranteed high vitamin C potency and, although the initial years of the project saw the importation of orange concentrate solely from U.S.A. under the Lease-Lend programme, more recently Palestinian and other juices have been produced of a satisfactory grade to meet the Ministry of Food's very stringent requirements.

The whole of this processing has been carried out by evaporation in vacuum and very little significant development has occurred with freezing concentration. Indeed, Government investigators to Germany after the last war were unable to discover any later fundamental information or illustration than those shown in the Technical Communication in this series (No. 11—Fruit Juices and Related Products) published in 1939. Consequently, attention will be paid almost entirely to various types of plant for vacuum concentration which were not mentioned or described in detail in the previous Communication.

(a) Mojonnier low-temperature evaporator

The Mojonnier Co. of Chicago have recently installed at Lake Wales, Florida, a new system of evaporation for orange juice that does not expose the fruit product to a temperature higher than 60° F. The plant utilizes the principle of secondary recompression in the following manner. Instead of attempting to compress the very large volumes of water vapour, the heat from this vapour is first transferred to another vapour which does not occupy so large a volume. This vapour is then compressed in the normal way. The precise method of operation is best described by a direct quotation: " Water is evaporated from orange juice at 60° F. At this temperature water vapour has a volume of 1,208 cu. ft. per pound. Through a heat exchanger, the latent heat of the water vapour is transferred to anhydrous ammonia, boiling at 45° F. The water vapour condenses in the shell, the ammonia vaporizes in the tubes and the net result is 2 lb. of ammonia vapour at 45° F. instead of 1 lb. of water vapour at 60° F. The volume, however, of the ammonia vapour is 7·2 cu. ft. instead of 1,208 cu. ft. in the case of the alternative vapour." It is claimed that amongst the advantages of this system are the use of extremely low quantities of water—or none at all, and the use of very low temperatures of evaporation leading to remarkably fresh flavours in the ultimate concentration. Under ideal conditions, neither steam nor water is needed for the operation of the Lo-Temp plant and with respect to thermal efficiency the apparatus is rated as equivalent to multiple effect evaporators.

Consumer tests have indicated the inability of many groups of tasters to determine the difference between reconstituted concentrates made by this process and straight juices that have not been subjected to any system of concentration at all.

The Figs 52-55 indicate the salient features of this plant. The last three are taken of the plant installed at Lake Wales, Florida. Fig. 52 shows by a line drawing the actual operation of the machine. The sequence of operations is described beneath the diagram. Fig. 53 illustrates the actual compressor used with the Lake Wales unit. Fig. 54 illustrates the entire plant on site, whilst Fig. 55 has been taken to give a view of the evaporation tubes showing the small sleeves that spread the orange juice in a thin film along the outside surface of the tubes.

(b) Kestner climbing film evaporator

This plant has been widely adopted in England and some European countries for the concentration of fruit juices. This system is particularly noted for its inclusion of an ancillary separator which " strips " the volatile fractions from the juice continuously and enables the aroma of the juice to be returned to the concentrate instead of being lost with the main body of the vapour through the condenser system.

The juice being introduced to the evaporator is heated to about 40° C.—i.e. to a temperature which will under the conditions of vacuum in the plant vaporize the volatile constituents of the juice with the minimum of water. The volatile fraction is continuously separated and condensed in a very efficient condenser, which, to obtain optimum results, should be cooled with ice-cold water. The juice, stripped of its esters, is fed to the first stage of the main evaporator—a series of tubes externally heated in a calandria heated by low pressure steam. The juice immediately takes up the form of a thin film rising with high velocity which, in itself, affords ideal conditions for good heat transfer. The vapour and partly concentrated juice are separated in a tangential separator, the concentrate then falling to the bottom of the calandria for passage through the second and third stages of evaporation. In actual fact, the tubes for the three stages are enclosed within the same calandria, thus ensuring a compact design and easy cleaning operations.

Evaporators of this type call for considerable quantities of cooling water if the temperature of evaporation is to be maintained at a reasonable figure. The temperature of the condenser water is of considerable importance and in many cases cooling towers must be installed to enable the same water to be recirculated. The vacuum is obtained by two-stage steam ejectors and, other conditions being suitable, the plant can operate at a vacuum of 27-28 inches. When once the flow through the evaporator is stabilized, the Kestner plant will function continuously for long periods. If the plant operates with an open catchpot for the concentrate (i.e. employs a barometric leg) there are no moving parts of any description and the operator's occupation tends to become monotonous. The quick flow of the liquor through the tubes is very advantageous as a preventive of flavour changes. The volatile fraction should be returned to the concentrate immediately, for in its normal state of concentration the flavours are not stable and it is possible for mould growth to develop in the aqueous solution even at 0° C.

The most usual off-take for the volatile fraction is 3-5 per cent. of the input. To re-incorporate this volume in the end product entails the concentration being taken to a somewhat higher soluble solids content than is ultimately required. In certain cases, an appreciable concentration of the volatile fraction can be effected by passing it through the plant again or through a smaller laboratory machine which has an input of 6-10 gallons per hour.

The Kestner plant provides high quality concentrates from apples and most soft fruits, but blackcurrants appear to be an exception. This may be due to two factors—the very high natural acidity of the juice, and the specific nature of the blackcurrant flavouring materials in the juice. A 7 : 1 concentrate may have an acidity of 28 per cent. citric acid, and this would have a detrimental effect on flavour due to excessive " cooking " of the juice during the evaporation process. Again, the volatile substances in the blackcurrant behave in a somewhat different manner from those in other soft fruits and apple, and it cannot yet be said that there is a process

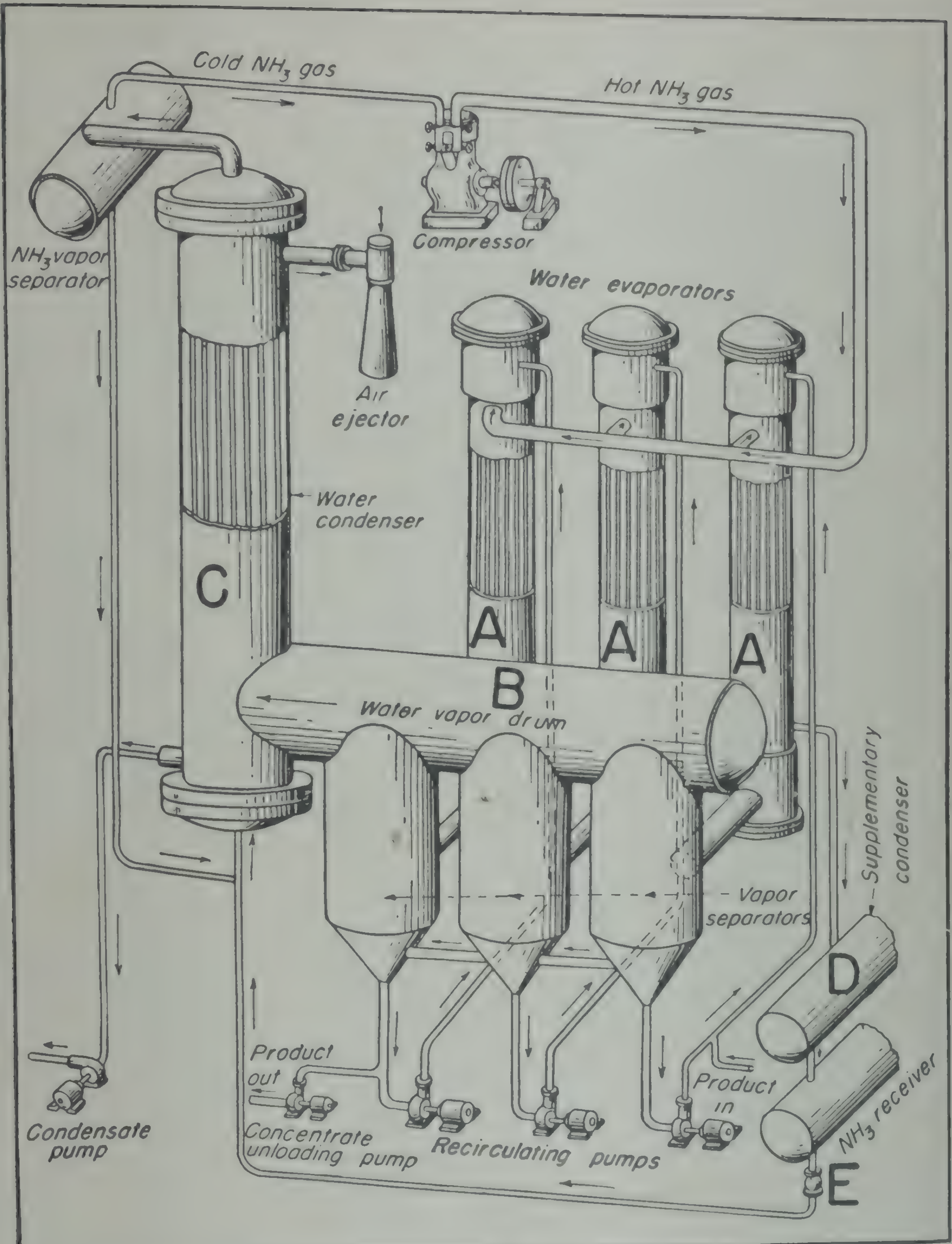

FIG. 52.

Mojonnier Lo-Temp Evaporator—Sequence of Operations.

Heat, latent in the compressed NH_3 vapour, causes orange juice to boil in shell and tube condensers (A). Water vapour from (A) is separated in drum (B), and passes into large shell and tube condenser (C). NH_3 liquefied by exchange of latent heat in (A) is further cooled in condenser (D) and passes through expansion valve (E) where it is vaporized in condensing the water vapour. NH_3 vapour returns to compressor, completing the cycle.

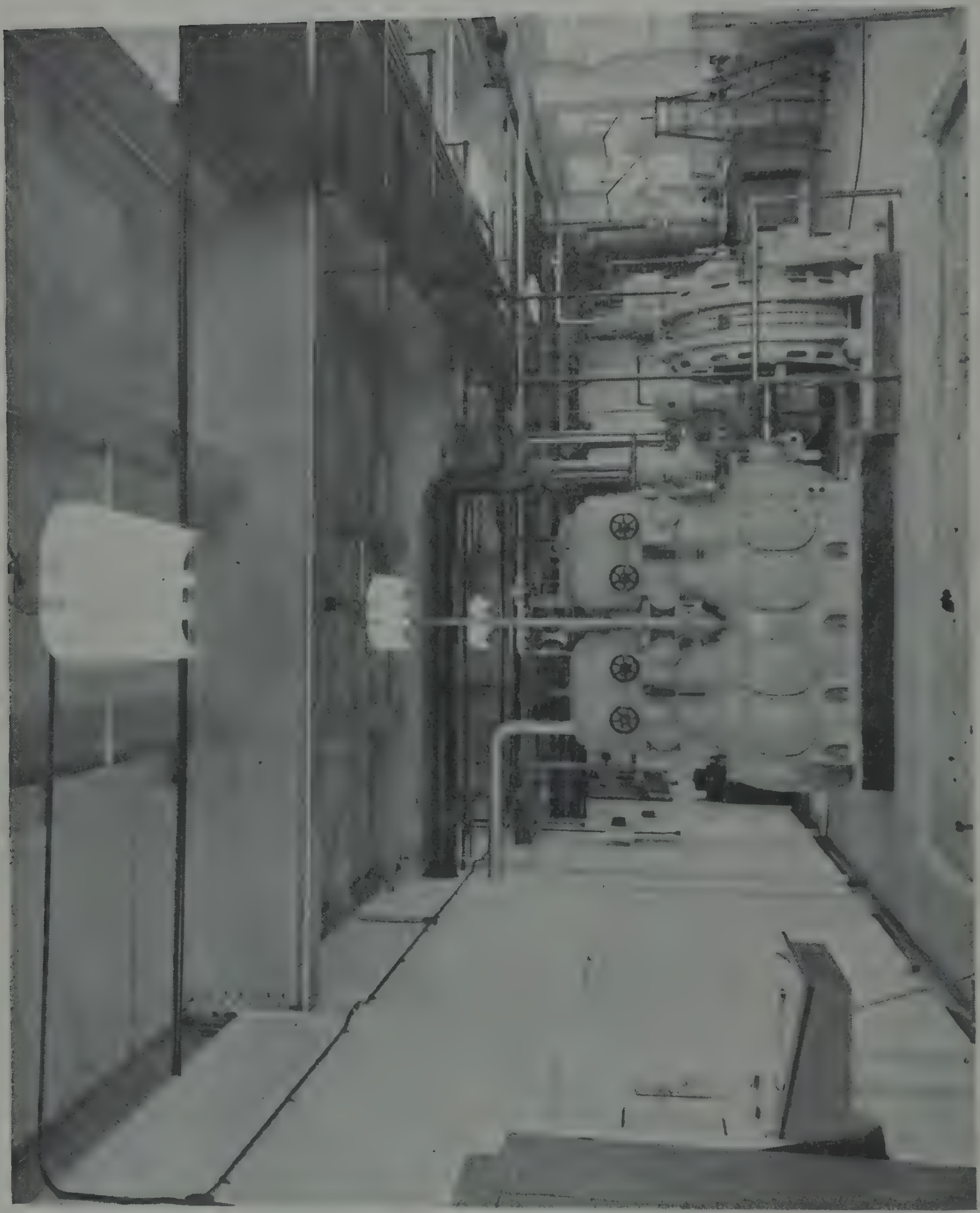

Fig. 53.
Compressor for use with Mojonnier Lo-Temp evaporator.

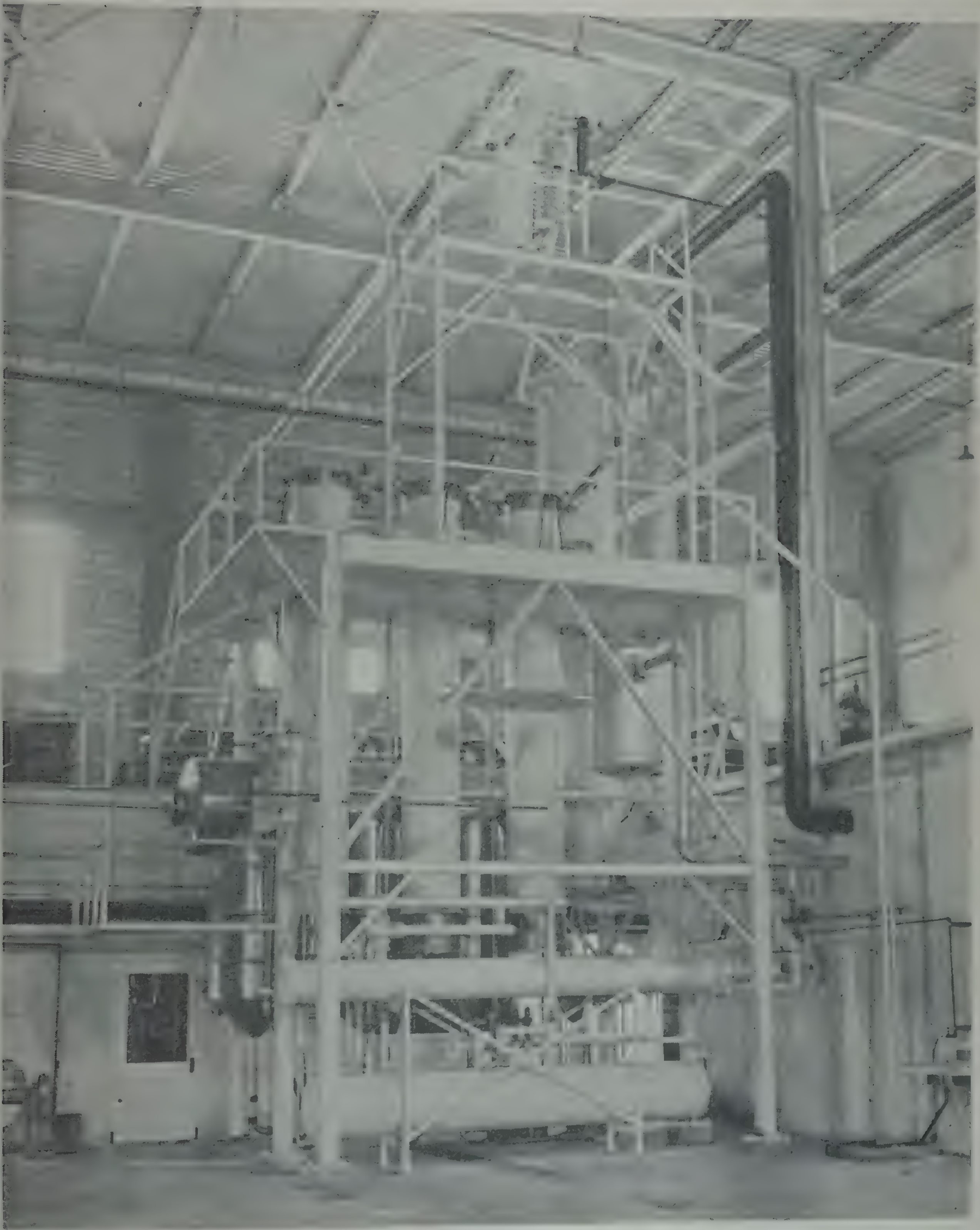

Fig. 54.
Mojonnier Lo-Temp evaporator installed at Lake Wales, Florida.

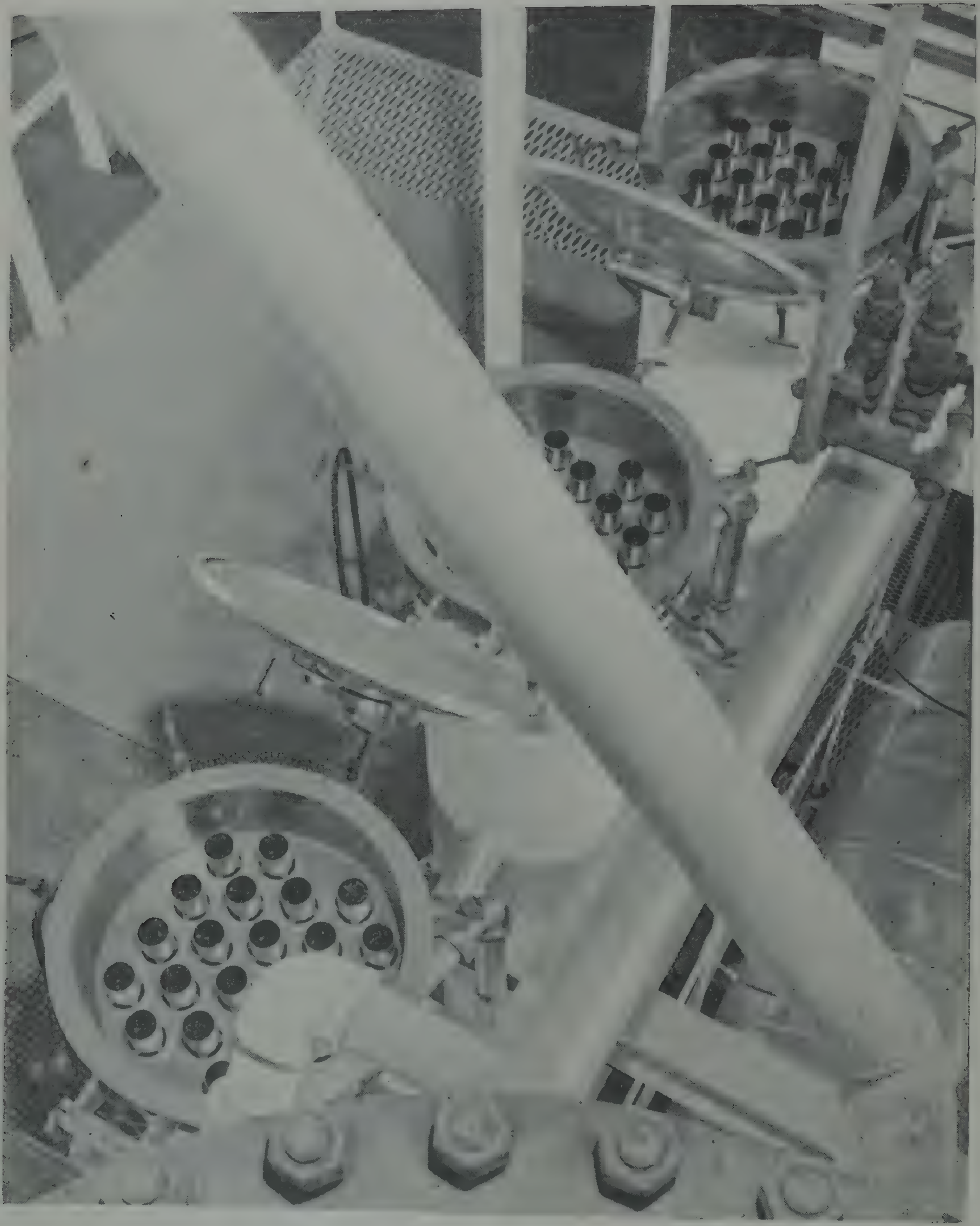

FIG. 55.
Mojonnier Lo-Temp evaporator: showing nests of evaporator tubes.

or the concentration of juice from this fruit which gives satisfactory flavour and vitamin C etention.

Figs. 56 and 57 show two sections of a Kestner evaporator designed specifically for fruit juice work.

(c) Fraser low temperature evaporator

Fig. 58 represents a stainless steel forced circulation evaporator with two external multitubular steam heated calandrias through which the liquid to be concentrated is circulated by the centrifugal pumps shown. The plant is run under a vacuum of not less than 29·5″ Hg. The steam in the calandrias is not usually under a pressure greater than one atmosphere, thus ensuring that the temperature of the 7 : 1 concentrate shall never exceed 153° F. A centrifugal separator is provided, by the use of which entrainment losses are so reduced as to become negligible. This type of plant is used for thermally sensitive materials, such as vegetable extracts and fruit juices. The surface condenser can be refrigerated in special circumstances.

(d) Swiss evaporators

In Switzerland, where power is relatively cheap but steam raising costs are high, there has been a move to develop evaporators using the system of total re-compression. Heat pumps are widely used, although their particular advantage of allowing a very low cooling water consumption is not of importance in that country. As an example of Swiss evaporators of recent design, the Sulzer machine may be mentioned. Fig. 59 illustrates such a plant designed specifically for fruit juices. An electrically operated turbo-compressor is installed and used as a heat pump. The photograph shows the separator in the foreground, and one of the tubular evaporators in the right background. In the left background can be seen the driving motor of the heat pump and the switchboard, whilst between the heat pump and the separator is the vapour cleaning and drying plant.

A further example of Swiss evaporating plant associated with the use of a thermo-compressor is that of the Brown-Boveri organization. Fig. 60 shows a complete plant for the evaporation of fruit juices, yeast extract, milk and for the distillation of water and various medicinal products in the chemical industry. The plant shown in the illustration is capable of concentrating fruit juices to one fourth of their initial volume and of removing 6,600 lb. of water per hour. Only 24 gallons of water are called for per minute for cooling purposes. The power in-put measured on the motor terminals is 186 kw. Evaporation takes place in this plant at about 130° F.

The Swiss technicians emphasize the need for considering every evaporation problem on its own merits. Single, double or triple stage systems each have their own functions, and the availability of cheap power and means of raising steam must all be considered before deciding on the best method in any particular case.

(e) Recovery of natural apple flavours

During the last war, a considerable production developed in America and Canada of a bland apple syrup which was used largely for its sweetening properties (5). There was no reason in such a product to retain any of the apple flavouring, and attempts were made to develop a process to separate, collect and concentrate these volatile materials. The main reference to this work is that of Milleville and Eskew from the Agricultural Research Administration of the Bureau of Agricultural and Industrial Chemistry, U.S. Department of Agriculture (4). These workers were able to produce a colourless watery solution of the natural volatile constituents of apples concentrated from 100 to 150-fold. Such a product showed indefinite keeping properties and when added to a good grade of apple concentrate produced a product which, on dilution, was indistinguishable from fresh juice.

The basis of the method is as follows : the fresh juice is heated to 320° F. under pressure and released into a flash chamber at atmospheric pressure to obtain a 10 per cent. vaporization. In the vapours from the flash chamber, the volatile constituents are present to an extent of

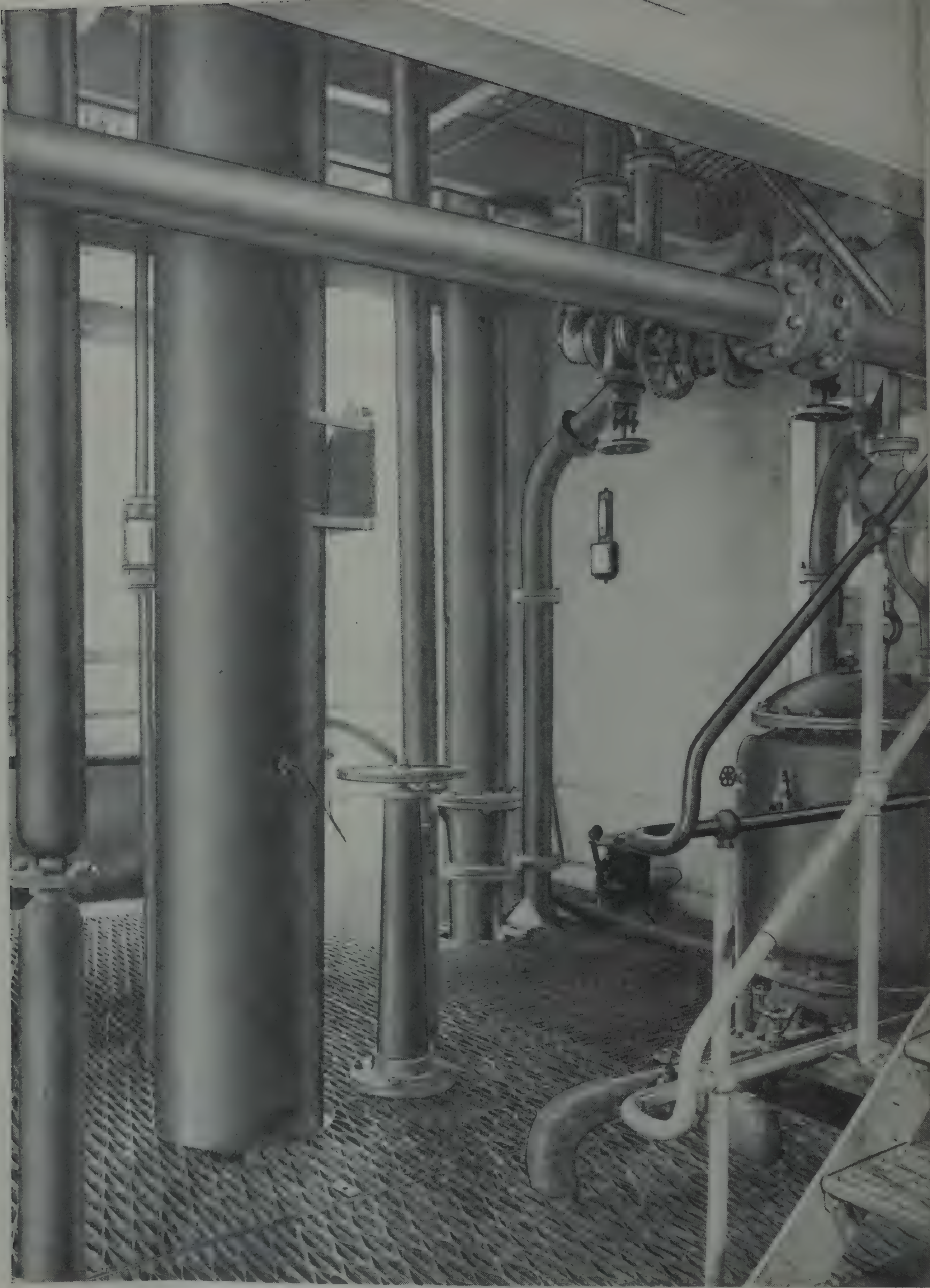

FIG. 56.

Kestner fruit juice evaporator. Working platform, showing wheel valve steam-regulator in calandria and compressor for ester take-off (on extreme right).

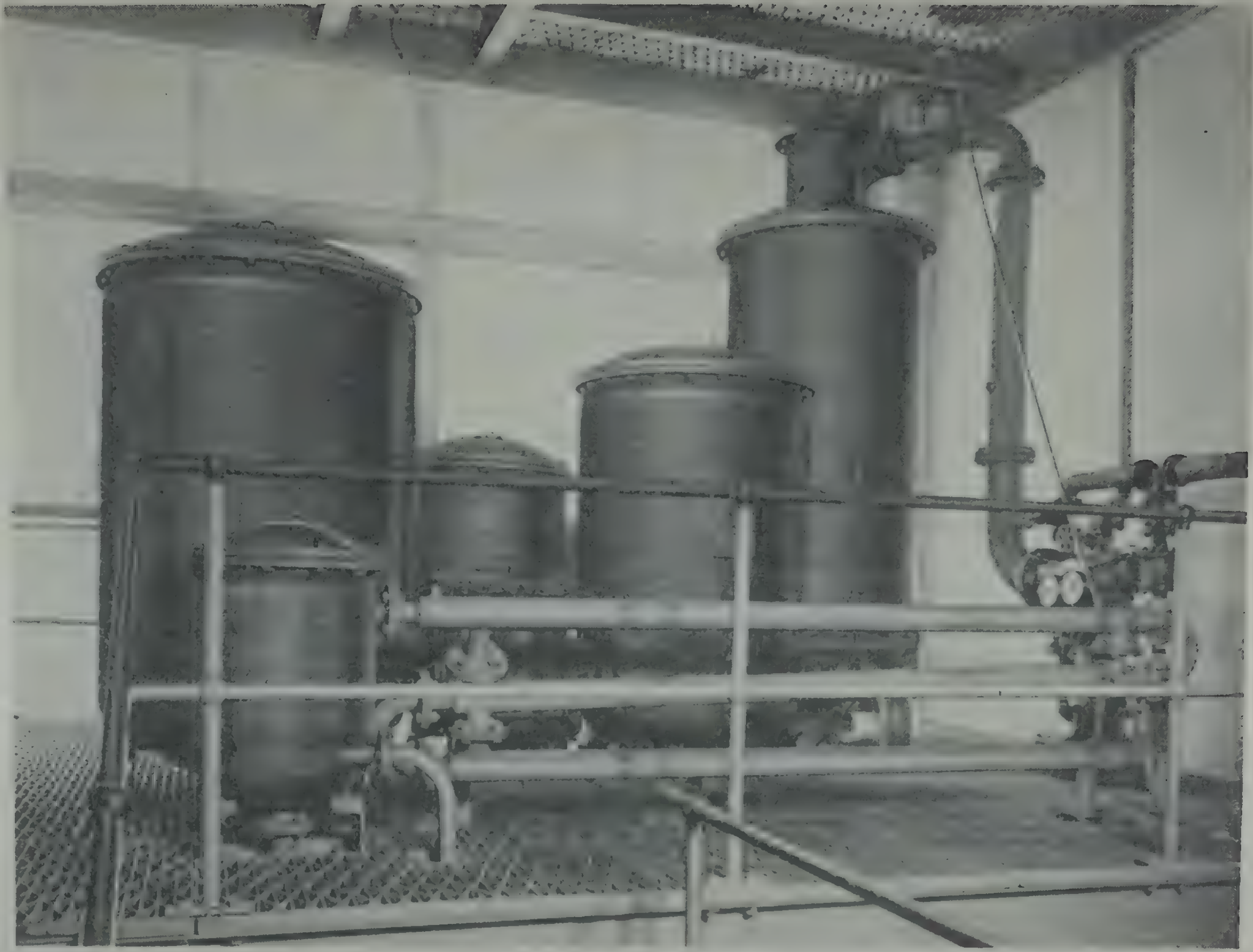

Fig. 57.

Kestner fruit juice evaporator.

Ester separator and condenser in foreground, with three vapour separators leading from top of calandria in the background and vapour condenser on extreme right.

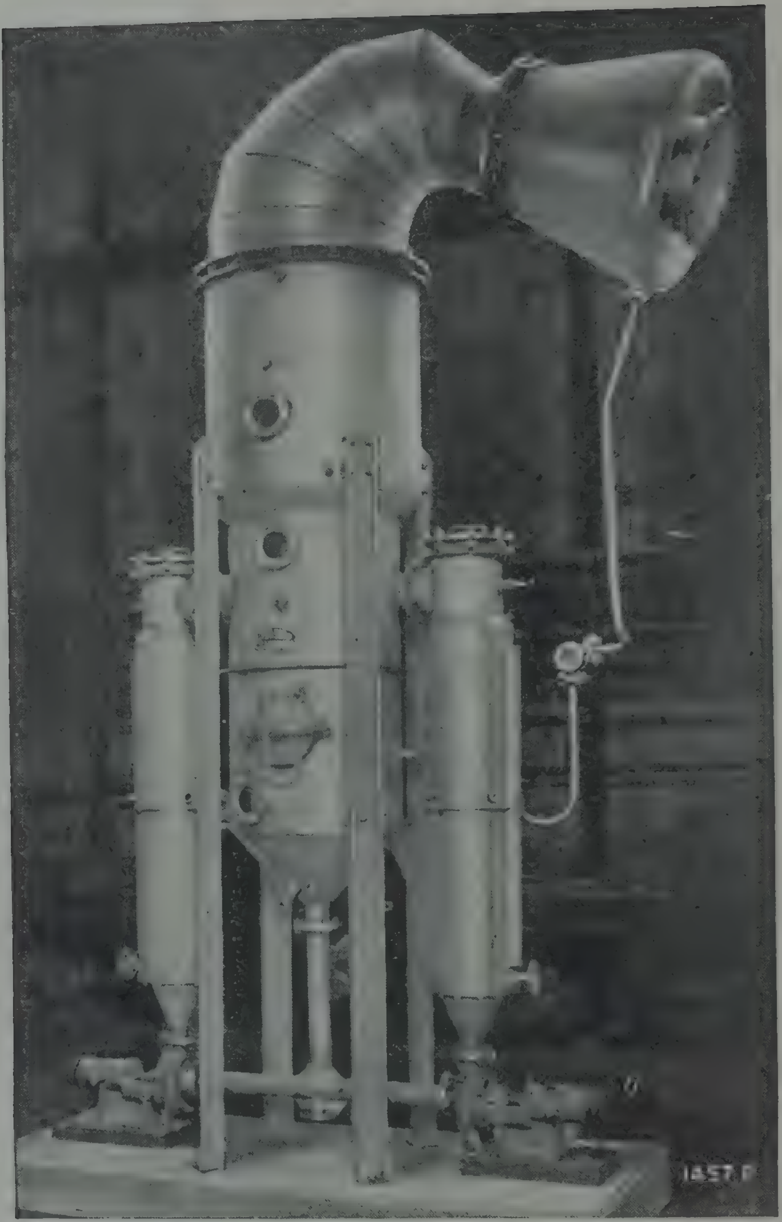

FIG. 58.

Fraser forced circulation evaporator.

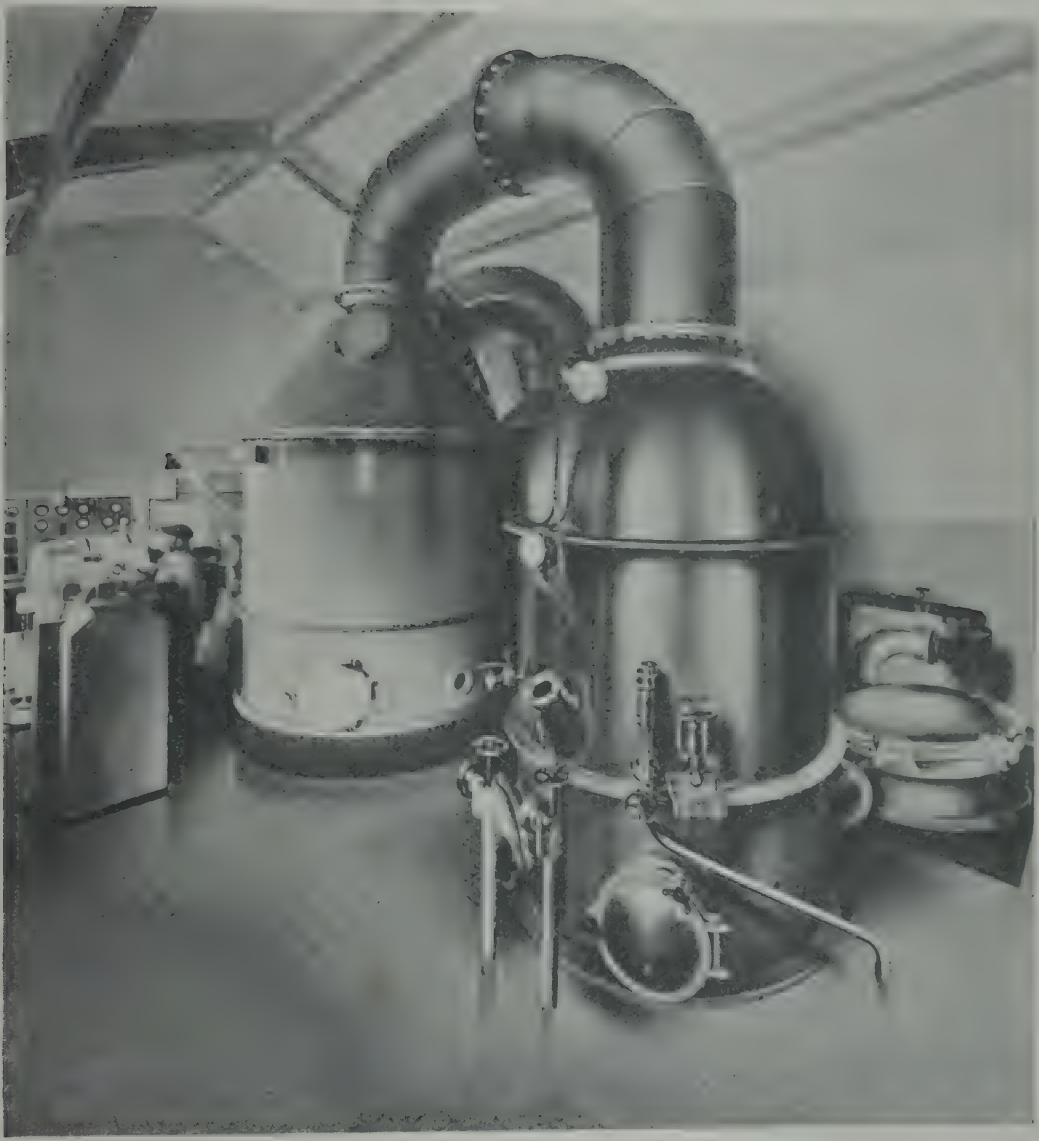

Fig. 59.

Sulzer evaporator for fruit juices.

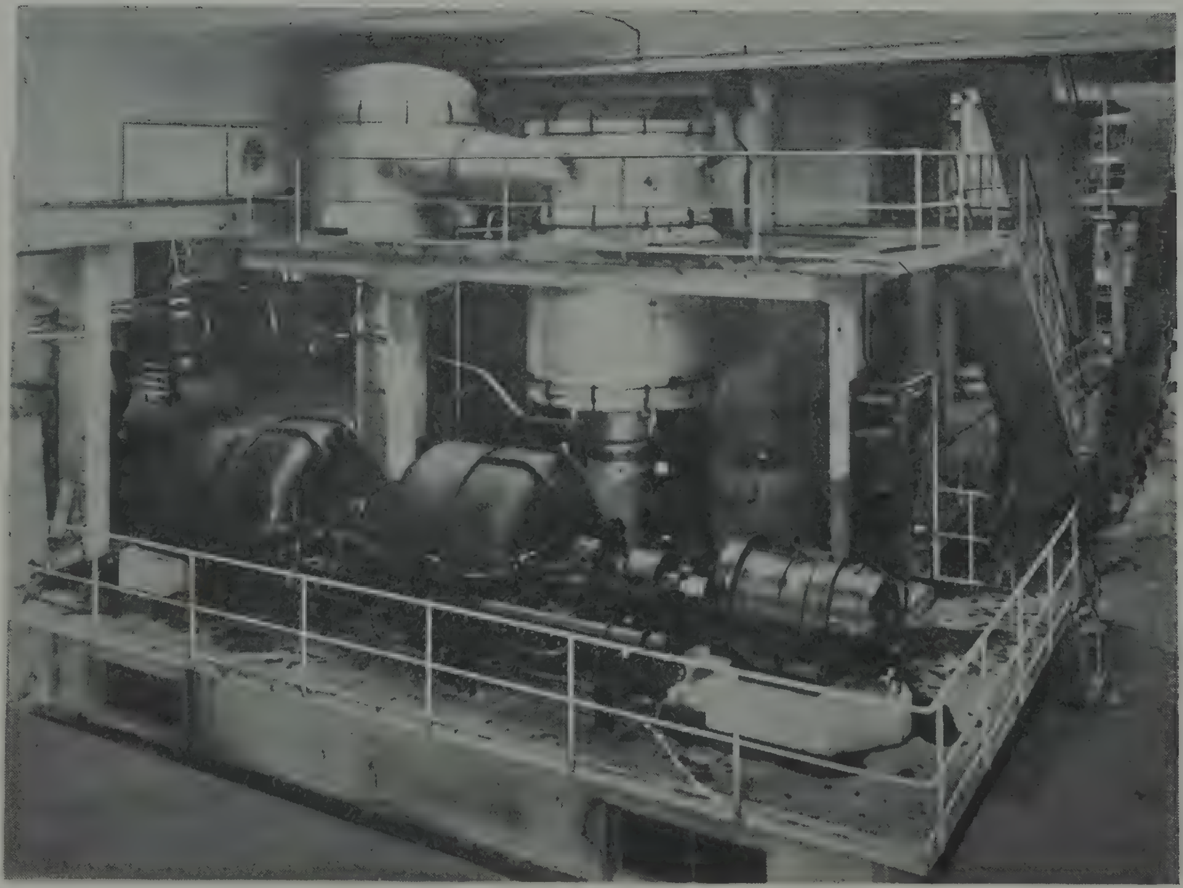

FIG. 60.

Brown-Boveri fruit juice evaporator with thermo-compressor.

ten times that of the original apple juice. The vapours are then fractionated until a concentration of 100-150 times that of the original is obtained.

The cost of the process was estimated in 1944 as being 30 cents per gallon, for a plant operating at the rate of 5,000 gallons of fresh juice per day. The investment for a new plant for the volatile recovery would be about $3,500.

In considering this process, it should be borne in mind that a certain amount of ethyl alcohol, originally present in the apples, will be carried over into the concentrated volatile fraction. It would appear that the Alcohol Tax Unit of the U.S. Bureau of Internal Revenue has taken the view that " since the essence is produced by distillation and since it may contain more than 0·5 per cent. alcohol, the essence may be subject to the usual restrictions concerning such products " (3, 6). Active efforts have been made to ensure the reduction of alcohol in the essence to a figure that would be acceptable to the Revenue authorities. One method that has shown some signs of success has been the reduction of the original vaporization from 10 per cent. to 5 per cent. or even 3 per cent. (8). The most recent development in this intriguing subject has been the improvement in the condensing system used in the original Milleville and Eskew plant so that a concentration of 800 : 1 has been obtained (i.e. 1 gallon of volatile substances is prepared from 800 gallons of fresh juice (7)).

The comparison of " essences " from nine varieties of apples has been undertaken by Griffin, Talley and Heller (2). It was found that each variety provided a volatile fraction that was characteristic of its own flavour, and that the end product could be used for a wide variety of purposes for the flavouring of candies and gums.

(f) Freezing concentration

Kertesz, an investigator for the U.S. Joint Intelligence Objective Agency of the United States, examined in 1945 the position in Germany as it affected the Krause freezing process of concentration. The following notes are taken extensively from Dr. Kertesz's report " Observations on the German Fruit Juice Industry ", *F.I.A.T. Final Report No.* 567.

Two main methods of concentrating unfermented fruit juices were used in Germany during recent years. The first one was by vacuum concentrators essentially of the types used until recently in the United States. The other method was concentration by freezing. This method has been applied to various products all over the world, but the first machine suitable for continuous commercial use was developed in Germany just before the war. A refrigerated drum slowly rotates in a trough containing the fruit juice. The coat of ice imbedding some concentrated juice is shaved off and pressed out in a worm press at 300 atm. pressure to remove the fruit juice. The ice removes usually less than 0·5 per cent. of the dissolved solids and is used subsequently for pre-cooling. This machine will be discussed here merely for its usefulness in producing high quality fruit juice concentrates.

There were at least five or six of these Krause drums in operation in Germany towards the end of the war, and a number more were being built. It is interesting to note that two such machines were either built or actually in the process of erection for use in Hungary to process berry juices for German use. This fact well demonstrates the high esteem in which German food technologists held the Linde-Krause drum, since the building of this machine involves a great deal of what was obviously critical material and equipment. The concentration was occasionally performed in several steps, reaching a final solids concentration of 30 to 50 per cent. The equipment was obviously not suitable for products like tomato juice where the system is essentially diphasic, i.e. composed of a solution and suspended solids. Its efficiency was reduced in cases where the original juice was very viscous. For this reason it was found useless for the concentration of pectin extracts. In order to increase the operating efficiency, the viscous fruit juices were usually treated with clarifying enzymes and then filtered clear. The production capacity of the machines was in the neighbourhood of 1100 lb. of concentrated juice per hour with a concentrating ratio of 1 : 2·5 and about 28 per cent. solids content. With higher solids concentrations the production was less, while with low original solids content the concentration was more efficient. It may be added that the Linde-Krause drum was extensively used for the concentration of vegetable juices, especially of onion and parsley juice, where in contrast with the use of vacuum pans a great deal of the typical " pungency " could be retained during the concentration.

Dr. Kertesz had occasion to taste a number of different fruit juices concentrated by this method. Both the apple and grape juices were of excellent flavour. The most impressive factor, however, was the high quality of the berry juices, especially raspberry juice, concentrated in this manner. Upon reconstitution it made a product of very fine aroma and flavour. It should be mentioned, however, that these concentrates were mostly preserved by the Seitz method without any use of elevated temperatures, a fact which may well account for some of their good quality.

The effect of freezing concentration on the ascorbic acid content of blackcurrant juice has been examined on the laboratory scale by Gane at the Cambridge Low Temperature Research Station (1). The juices were frozen in constant temperature rooms held at −3° C., −7° C., −10° C. and −20° C. The concentrate was separated from the ice matrix in a basket type centrifuge, developing an acceleration of 800 G. Apple, damson, plum, strawberry and blackcurrant juices were concentrated by this means up to 9·7 : 1 (strawberry), but reference will only be made here to the results on the blackcurrant juices with respect to the ascorbic acid content. The concentration of ascorbic acid in the blackcurrant juice appeared to proceed more rapidly than that of the other solutes during freezing, and the final products were very rich in vitamin C. Some data on blackcurrant juices from Gane's paper are given here :

VITAMIN CONTENT OF CONCENTRATED BLACKCURRANT JUICE

	Total Solids g. per 100 g. juice	Ascorbic Acid mg. per 100 g.		Concentration Ratios	
				Total Solids	Ascorbic Acid
		(1)	(2)		
Black Currant Juice A :					
Original juice ..	13·50	1·13	1·37	1·00	1·00
Concentrate I ..	25·40	2·33	2·69	1·90	2·05
II ..	40·40	4·83	4·73	3·00	4·30
III ..	53·90	6·55	6·56	4·00	5·80

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7 ———. Communication to the Editor. *Ibid.*, **27** : 216, 1948.

8 ———. Communication to the Editor. *Ibid.*, **27** : 296, 1948.

CHAPTER VI

CITRUS JUICE AND OIL EXTRACTION

In the modern citrus juice industry the removal of both the juice and the oil are of equal importance. Only a few years ago, the fruits were used largely for the production of their essential oils and the juices were of relatively minor importance. The rapid strides made in popularizing citrus juices at cheap prices have now made it incumbent upon the processor to make profitable use of every part of the orange or other fruit, and this process is actually extended to include the extraction of pectin from the waste material and the drying of the extracted pulp to provide a feeding stuff for stock. There have been many very important developments in the last few years concerning the methods of juice and oil removal. Some machines are designed to perform both duties simultaneously, but others are specifically employed for one or the other of the single processes.

The time-honoured method of using mechanical reaming machines (i.e. revolving lemon squeezers on which the halved fruits were pressed by hand by rows of operators) is still in force, although to a much less extent than formerly. The reamed juice is de-aerated immediately after it is collected from the extraction machine and then processed in various ways to suit the final purpose for which it is required. The chief concern in extracting citrus juices is to avoid any admixture of the bitter principles of the pith tissue or of the essential oils from the outer skin. The hand reaming method depends for its success on the skill of the operative in avoiding these two undesirable features, and the most recent developments concern the mechanized removal of the juice without hand operation. One or two of these machines will be described later.

Essential oils are now almost entirely recovered from the fruit by mechanized means. The older, laborious hand operations are now practically superseded by elaborate and highly efficient machines, although it is interesting to note that large amounts of orange oil of very high quality are produced by hand in French Guinea in West Africa. Here the oil is obtained by scraping the skin of the fruit with a sharpened spoon which breaks the oil sacs and receives very minute amounts of oil in the bowl of the spoon. One boy can produce about a quarter of a gallon of oil per day, but the quality is excellent.

Practically all methods of oil removal involve the use of sprays of water to carry the oil away from the fruit skins. This water, if used to excess, can adversely affect the quality of the oils both on account of the chemical changes it can cause in the oils themselves and because the water dissolves certain soluble constituents of the natural oils, without which the final product cannot be regarded as being correctly balanced. Those processes that avoid the use of water entirely are thus capable of producing the very highest quality of oils. The " old-fashioned " sponging method certainly produces oils of this superfine quality.

The chief methods of juice and oil extraction in use at the present time are as follows :

(a) Screw press

This uses peels only and the oil is expressed by the action of a tapering screw revolving within a stainless steel casing. The oil is recovered through a strainer in the bottom of the casing, whilst the residual tissue is expelled through the end of the cylinder.

(b) " Brown " juice extractor

This machine represents one of the latest developments of reaming halved fruits (Fig. 61). The whole procedure is highly mechanized and provides both high quality juices for canning as well as peels from which the oil can be removed by an additional machine.

(c) Food Machinery Corporation super-juicer

The latest type of machine, introduced in 1947, has gained wide acceptance in a very short time and is now in use in America (California, Arizona, Texas and Florida) as well as in Tunisia, Palestine, South Africa and Southern Rhodesia. The machine is shown in Fig. 62. It functions both as a juice and oil extractor. Graded fruit fall into a spherical fitment formed of a series of interlocking fingers which grip the fruit on all sides with equal pressure. The lower section of the fitment is provided with a tube with a sharpened end which cuts out a plug of the skin and serves to remove the juice when pressure is applied to the fruits. Increase of pressure over and above that needed to express the juice disrupts the oil sacs and the oils run into a receptacle from which they are taken to a centrifuge for separation of oil from the aqueous phase. At this stage the interlocking fingers release their grip on the fruit peel, which is ejected and dried as a by-product for pectin or feeding stuff.

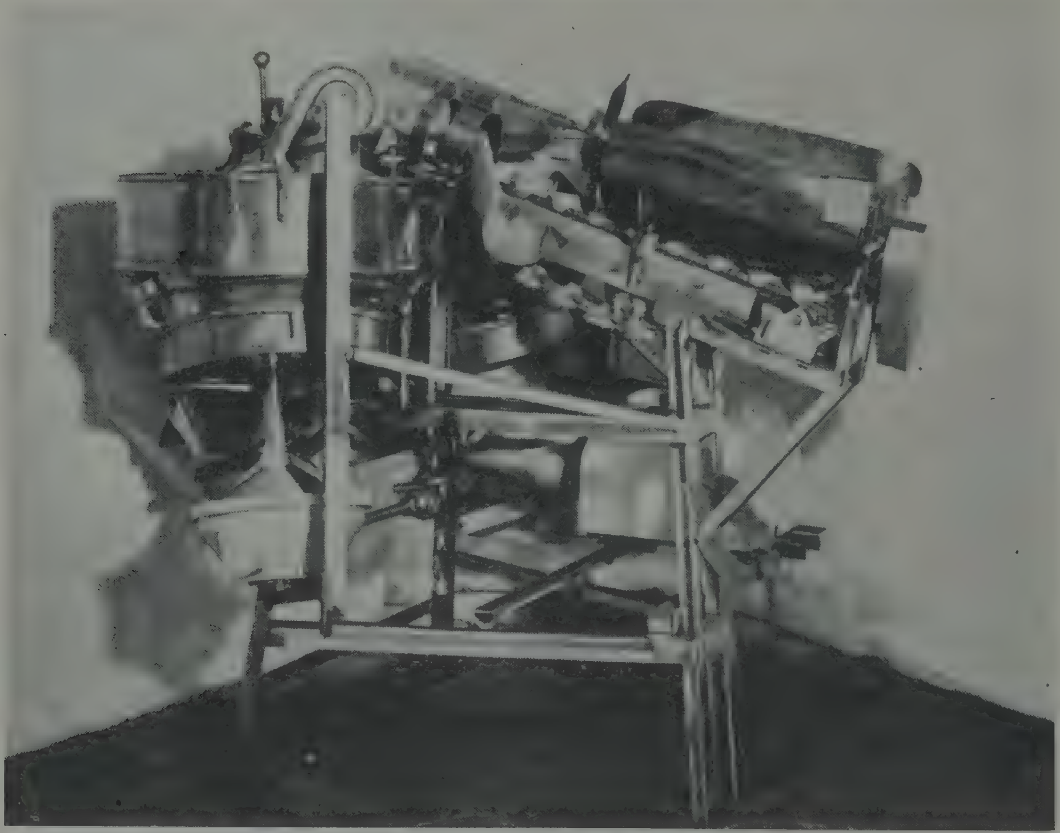

FIG. 61.
Brown fruit juice extractor.

This process has one great advantage in that the juice and oil are removed from the fruit by two quite separate channels which avoid the possibility of mixing oil and juice. The absence of the use of sprays of water is a further improvement which contributes to the efficiency of the machine.

(d) "Pipkin" oil press

This machine utilizes only peels from which the juice has been removed. Two heavy, slowly rotating cylinders are set closely together. They are provided with grooves to facilitate removal of the oil and other liquids expressed from the peels; no water is needed to remove the oils. (Fig. 63.)

(e) Italian " Avena " machine

The surface of the fruit is lacerated and rasped by its violent erratic movement against a surface supplied with abrasive material and sharp projections. The oil is removed by water sprays (Fig. 64).

For an up-to-date full review of the citrus oil industry attention is drawn to " Citrus Oils and their Methods of Extraction " by Guenther (*Food Packer*, September and October, 1948), and to " Citrus Products " by J. B. S. Braverman, published by Interscience Publishers, Inc., New York, 1949.

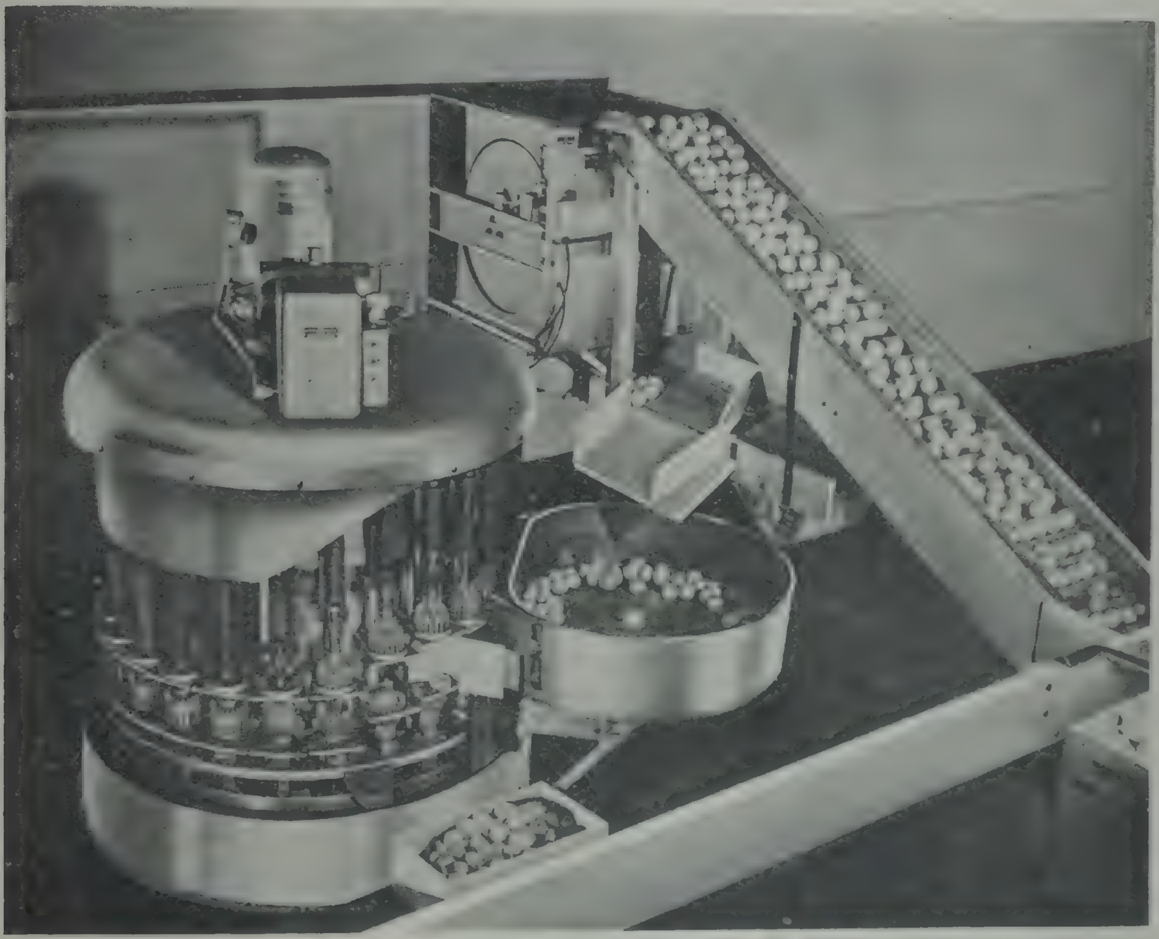

FIG. 62.

" Super-Juicer " for extraction of citrus juices and oils. (Food Machinery Corporation.)

(f) Taglith juice and oil extractor

These machines are of very recent introduction but have already proved to be most acceptable to the Palestinian citrus juice industry. They owe their development to the genius of Dr. Max Koffler.

(i) *Juice extractor :* The oranges are fed by an elevator into the cups of one of two drums rotating in opposite directions. They are pressed on to a static knife to be halved. On reaching the lowest point the halves are met by vertically moving, smooth, perforated heads and the juice is pressed out. The juice actually flows through the perforations in the heads and flows away into channels. A feature of the design is that due to the vertical movement of the heads a protective layer of the already pressed-out cells is formed against the albedo of the peel,

CHAPTER VII

VITAMIN FRUIT SYRUPS

The British Ministries of Food, Health and Supply introduced in the last war three vitamin fruit syrups, two of which, blackcurrant and orange, were produced to the order of the Ministry of Food for distribution to children through its Welfare Food clinics; the other, rose hip syrup, was prepared under the sponsorship of the Medical Directorate of the Ministry of Supply for general consumption by civilians in need of vitamin C, but who did not qualify for supplementary vitamins under the Ministry of Food scheme. At a later date, the rose hip scheme was taken over by the Ministry of Health. The first of these projects was commenced in 1940, when the Scientific Advisor's Division of the Ministry of Food was concerned over the vitamin C status of children in the lower age groups; the manufacture of blackcurrant syrup and purée was initiated for the Ministry, the products being distributed to children up to the age of two years. The immediate success of the scheme led naturally to the desire to increase the age range of beneficiaries, but the blackcurrant crop in England could not cope with the demand, and a fresh source of supply was sought. Eventually it was found in concentrated orange juice from U.S.A., and enormous quantities were transported to this country throughout the rest of the war. The scheme continued after the war and in 1949 it appeared to have become a permanent feature of the Welfare Food Scheme. When the orange juice distribution had become fully established, the blackcurrant syrup and purée were still controlled by the Ministry; the products were distributed through chemists, but were available only for the use of children, expectant mothers and invalids. These restrictions were removed in 1949.

The rose hip syrup scheme was organized as a means of providing a supplementary source of natural vitamin C outside the Welfare Scheme, but this product has always been available to the general public and its production is no longer controlled by a Ministry, although the Ministry of Health's goodwill is extended to the manufacture and distribution of the syrup.

These three schemes represent new and significant developments in which fruit syrups have played and still play important roles in national nutrition. During the war, when fresh fruit supplies were disorganized, many hundreds of thousands of children were dependent to a large extent on their daily supplement of vitamin fruit syrup or purée to maintain their vitamin C level. Such schemes should have an appeal to other countries where supplies of fruits rich in vitamin C are available and where there is a sub-standard condition of vitamin C nutrition. In India, for example, enormous quantities of oranges, rose hips and emblic (amla) are available at very reasonable cost and all these fruits could be processed for the benefit of the millions of inhabitants of that sub-continent whose needs for vitamin C constitute a colossal problem nutrition.

The production of these syrups will be briefly described here.

Blackcurrant syrup

Firm, ripe fruit from selected varieties only is chosen for processing. The fruit must be processed in a fresh condition and aluminium trays holding 28 lb. each are favoured to prevent undue crushing of the fruit in transport. The berries are milled to a pulp which is pumped away to stainless steel tanks in which the pectin-decomposing enzyme is added. During the war Pectinol 10M was used at a strength of 0·03 per cent. for 48 hours, but as production increased the period allowable for the enzyme action was reduced to 24 hours and the enzyme was increased to 0·06 per cent. or even 0·1 per cent. in cases where extremely quick turn-over of tanks was necessary. The completion of pectin degradation is assessed by relative viscosity determinations, after which the pulp is pressed in the usual type of hydraulic press with racks and cloths. A worsted cloth is preferred to the more usual cotton material used for apples. The juice is centrifuged and stored in high pressure tanks, or in low pressure tanks installed in a cold room (see pp. 20, 32). Alternatively, a syrup of 55° or 60° Brix can be made immediately, preserved with 0·035 per cent. sulphur dioxide, filtered and stored under as cool conditions as possible.

The stability of the ascorbic acid in juice or syrup stored under ideal conditions is remarkable. In fact, evidence suggests both that the blackcurrant syrup is the most stable form of natural ascorbic acid, and that this stability is to a large extent due to certain constituents of the fruit which are associated with the colouring materials. The finished product is pasteurized and sold under a guarantee of a minimum ascorbic acid content of 70 mg. per 100 ml. (or 55 mg. per 100 g., or 20 mg. per fluid ounce).

The product has been primarily used merely as a source of vitamin C, but during the war years it was found to be of great value as a relief for hyperacidity and gastric disorders in general. It was permitted by the Ministry to be used in factory canteens engaged on war production provided that it was not generally available to all workers, but only on the advice of qualified medical or dietetic practitioners. Its use was also extended when it was found suitable as a flavouring for milk, for it was often found that children and adults who could not take straight milk with acceptance were able to retain milk flavoured with the blackcurrant syrup. (Incidentally, the same can be said of other fruit syrups such as strawberry, raspberry and loganberry.) It is not thought that the value of blackcurrant syrup in these cases is entirely due to its ascorbic acid content, but the actual factors involved are not yet known.

Sweetened, concentrated orange juice

As this product is eventually sold in a 5 : 1 or 6 : 1 concentrated form, some removal of natural tissue has to be effected to facilitate both the concentration process and the later blending treatment and bottling of the juice. The juice running from the reamers is screened by passage through a $\frac{1}{32}$" sieve, and after de-aeration and flash pasteurization is concentrated, generally in batch evaporators running at high vacua. The concentrate is canned in plain, U.S.A., gallon cans. The concentrate can be filled hot, thus avoiding the need for a subsequent cooking process in the cans. On receipt in England, the concentrates contain between 150-300 mg. per 100 g. of ascorbic acid, averaging about 230 mg. The standardization at the British end involves blending of various concentrates to obtain a given acidity and an ascorbic acid content in the bottled product of 160 mg. per 100 g. (200 mg. per 100 ml., or 70 mg. per fluid ounce). The product is preserved with 0·035 per cent. sulphur dioxide, the reason being that the strength of the syrup (63°-65° Brix) is not sufficient to render it completely free from danger of fermentation after the bottle has once been opened and the contents become vulnerable to the action of airborne organisms. The production and distribution of the orange juice represented one of the first attempts to bottle a *concentrated* fruit product and the many unforeseen difficulties encountered were only overcome by strict hygiene in the bottling room and its plant. Stainless steel equipment should be used wherever possible, and wooden vessels and utensils completely forbidden. The latest development has been the introduction of a process of flash pasteurization of the juice immediately before being bottled. The maintenance of a temperature of 82°-83° C. for 5 minutes enables the syrup to be received into the bottles at 70° C., which is sufficiently high to ensure the sterilization of the bottles.

Rose hip syrup

The people of Scandinavia and Russia had been known for many years to have used rose hips as additions to their diet during winter months, and before the last war the Hitler regime was responsible for the planting of rose bushes along the German motor roads (autobahnen) which had been built for strategic purposes. The hips were picked by the local residents of the area through which the road proceeded and the sacks of fruit were collected at a central processing station. No firm details were, however, available of any method of making a syrup from hips when the Ministry of Supply started their scheme in 1941. It was found that the ascorbic acid in the milled hips was extremely vulnerable to oxidation until the enzyme systems had been inactivated by heat. On the other hand, the hard, waxy skin of the fruit resisted the penetration of hot water so efficiently that the mere boiling of whole hips in water was quite inefficient for extraction purposes. The hips should be disintegrated into halves or quarters and the seeds, which contain no ascorbic acid, separated at once. The husks must then be raised to a temperature above 70° C. in the shortest possible time by the percolation of water at 90°-100° C. The optimum extraction of ascorbic acid is achieved in varying times according to the condition of the hips, their pectin content being particularly important in this connection. Highly pectinous hips confer such a viscosity on the extract that the percolation is retarded so that more than one hour is needed for completion instead of 45 minutes as is usually the case. The extract may need enzyme action, in which case it is cooled to below 50° C. and treated with pectin enzymes for 3-8 hours ; centrifugation follows to remove finely divided tissues and the notorious barbed hairs which must not on any account gain access to the syrup. The extract is then concentrated to a degree depending on its richness in ascorbic acid. Sufficient sugar may be added to the extract so that the final concentrate, when the ascorbic acid is correct, registers 64° Brix. The syrup may be preserved with 0·035 per cent. sulphur dioxide for the same reason as for orange juice. When the extract possesses a very high ascorbic acid content and the subsequent concentration process effects only a slight reduction in volume, the syrup may be filtered through a Meta-filter or some similar filter using diatomaceous earth, but generally the product is sold in a cloudy condition.

With hips from southern English counties, where the ascorbic acid is relatively low, and the extract calls for considerable concentration, it is essential to use soft water for the percolation process to prevent a considerable deposition of calcium citrate in the bottled product after pasteurization.

The guarantees for vitamin content of rose hip syrup are similar to those for the Ministry of Food orange juice.

The rose hip and blackcurrant syrups have acidities much lower than Welfare orange juice and this may be the reason why the two former products are tolerated by some people who cannot take the citrus material.

Some details have become available since the war regarding German methods of rose hip syrup production. [*U.S. F.I.A.T. Final Report* No. **235**, 1945.] Hips were imported from Bulgaria and Syria to supplement the home-grown crop. The hips were crushed and allowed to stand overnight with water and sugar. The supernatant liquor was then mixed with the extract recovered by pressing the residue, the combined material being filtered, pasteurized at 75°-80° C. for 1 minute and concentrated. The finished product was not accurately standardized and the ascorbic acid content varied between 80-200 mg. per 100 g.

CHAPTER VIII

STORAGE OF FRUIT JUICES AND SYRUPS BY FREEZING*

The demand by the public at all times of the year for fruit juices which are identical n flavour with the natural products immediately they are squeezed from the fresh fruit has led o the development of many methods of retaining the fresh flavour by freezing the juices and toring them at very low temperatures until offered for sale. Many difficulties have been ncountered with regard to appearance of the thawed juice, but these have been overcome o such an extent that the future of frozen juices seems assured, at any rate in countries where efrigeration is in widespread use. The industry is at the same time almost entirely confined o the North American continent and the brief details given here are taken from "The Commercial Freezing of Fruit Products" by Joslyn and Hohl, Bulletin No. 703 of the California Agricultural Experimental Station, published in January 1948.

Orange juice

Fully ripe, fresh Valencias alone are suitable ; the Brix-acid ratio of the juice is preferred by American consumers to be 14 : 1. The usual sorting of fruit must be carefully carried out, after which the oranges must be washed, scrubbed, rinsed and dried. The fruits are fed to some form of automatic juice extractor which obviates contact of the juice with air or rag from the fruit. The juice is strained in a helical screw strainer with perforations not exceeding 0·030″ in diameter. The strained juice is then de-aerated. A variety of treatments are then open to the processor. The juice can be cooled to 40° F. and filled into citrus-enamel-lined cans which are immediately seamed under vacuum. On the other hand, if a moisture-proof bag is to be used as an insert in a cardboard carton, the juice should be flash pasteurized at 200° F. for 15 seconds and then cooled to 70° F. or below—this to inactivate pectic enzymes.

The packaged juices must be frozen as quickly and completely as possible in refrigerated alcohol at −40° F. or in very cold air blasts. The largest can that is suitable for this process is the American gallon size. Larger containers should be filled with juice already frozen to the consistency of a thick ice.

Other fruit juices

Apples, soft fruit, passion fruit, cherries and pineapples have all been used from time to time as bases for frozen juices, but none has ever received the same consumer preference as the orange. Each fruit presents its own specific difficulties, but these are chiefly concerned with the tendency of the tissue to separate from the juice unless methods of preparation and storage temperatures are suitably arranged.

Both clear and cloudy apple juices are prepared in a frozen condition and find a certain market, but frozen tomato juice has not been successful in view of the remarkable popularity of the normal heat-treated canned product.

Fruit syrups

The retention of flavour in a frozen fruit syrup is very much superior to that of the corresponding juice, and in recent years some firms have undertaken the commercial production of a series of frozen syrups from citrus and soft fruits (particularly loganberries, youngberries and boysenberries). The syrups are prepared by dissolving 7 lb. sugar in each gallon of pure fruit juice ; the syrup is de-aerated, packaged and frozen. Such frozen syrups are convenient for the home production of beverages, for it is only necessary to add three volumes of water to one volume of frozen syrup to provide very acceptable beverages when the solid phase has melted.

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* See also Chapter II, p. 22, for details of the Escher Wyss process.

CHAPTER IX

FACTORS AFFECTING QUALITY AND NUTRITIVE VALUE OF TOMATO JUICE*

By

F. E. Atkinson and C. C. Strachan

Tomato juice is the most important natural source of ascorbic acid (vitamin C) being packed in volume in Canada at a reasonable cost to consumers. When selected varieties of tomatoes are properly grown, prepared and processed, canned tomato juice should not only be attractive and palatable, but provide a good source of ascorbic acid, and contribute significant quantities of vitamin A.

A number of factors influence the quality and nutritive value of tomato juice. Except for results of work completed during the past two years, much of the information presented here in condensed form may be found in greater detail in two other publications by Strachan and Atkinson (17) and Strachan (16).

The effect of variety and season

While a number of factors may affect the ascorbic acid value of raw tomatoes, the two most important appear to be variety and climate. In Tables 6 and 7 are presented the ascorbic acid values for forty-two different varieties and strains of tomatoes grown under the same conditions at the Dominion Experimental Station, Summerland, B.C. Replicate samples of the canned product were employed for the determination of the ascorbic acid content of the different varieties. The loss of ascorbic acid in the canning process under proper conditions is insignificant and is comparable for all varieties being tested. For the variety tests reported in Tables 6 and 7 the canned product was stored for 8 months at 50° to 60° F. before being analysed, this treatment resulting in only a very slight reduction of the ascorbic content of the canned tomatoes. Due allowance was made for any interference of metallic ions.

It will be noted from Tables 6 and 7 that there was marked variation in ascorbic acid content of varieties. Also, while there was considerable variation in ascorbic acid values in the same variety from year to year and even from one picking to another, the varieties tended to maintain their relative position one to another, especially where average differences were marked. These results are in general agreement with the current literature on this question. The Signet variety developed at the Summerland Station is outstanding in its consistently high ascorbic acid content, having a 5-year average of 27 mg. of ascorbic acid. It is of good colour and makes a fine juice, but it lacks size for a good commercial canning tomato. Clarks Early and Sugawara have proved to have consistently good ascorbic acid values, but are not outstanding for flavour. Fortunately, Clarks Early and Sugawara have good cultural and canning characteristics which make them satisfactory canning varieties under commercial conditions in the Okanagan Valley and adjacent areas. Stokesdale No. 4 on two years' trial had a very good ascorbic acid content of 24 to 32 mg. per 100 g. and has proved to be an excellent tomato for canning. It has a deep attractive red colour which should make it satisfactory for juice also. In recent tests, Sioux and Valiant varieties have been found not only to have a fairly good ascorbic acid content of 19 to 25 mg., but also to have good canning characteristics.

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* With special reference to Canadian conditions and forming part of Publ. 813 or Tech. Bull. 68 of the Department of Agriculture of Canada.

TABLE 7

ASCORBIC ACID CONTENT OF THIRTY-SIX VARIETIES AND STRAINS OF TOMATOES GROWN AT SUMMERLAND, B.C.*

Variety or strain	Ascorbic acid content in milligrams per 100 grams of canned product†					
	1941	1942	1943	1944	1945	1946
	mg.	mg.	mg.	mg.	mg.	mg.
Master Marglobe (Stokes)	31	—	—	—	21	—
Marglobe × Bonny Best	30	—	—	—	—	—
Signet × Sugawara	—	—	—	30	—	—
Stokesdale (Stokes)	29	—	—	—	—	—
Hybrid 101	—	—	—	—	29	—
Hybrid 107	—	—	—	—	29	—
Sugawara × Signet	—	—	28	28	—	—
Valiant (Stokes)	28	—	—	—	—	22
Stokesdale No. 4	—	—	—	—	—	27
Splendid	—	—	—	—	—	26
Vetomold	—	—	—	—	—	26
Hybrid No. 8	—	—	—	—	26	—
Hybrid No. 119	—	—	—	—	26	—
Globonnie	26	—	—	—	—	—
Essary (Univ. of Tenn.)	26	—	—	—	—	—
Asgrow Scarlet Dawn	—	—	—	24	—	—
Hybrid No. 46 (Mich.)	24	—	—	—	—	—
Stokesdale No. 48	—	—	—	—	—	24
California Dawn	—	24	23	—	18	—
Harkness Early	25	20	25	—	—	—
Bestal (Sd.)	23	25	21	—	—	—
Earliana Sport (8040)	—	25	21	—	22	19
Rutgers (Vineland)	22	—	—	—	—	—
Rutgers (Stokes)	22	—	—	—	—	—
Signet × California Dawn	—	—	—	22	—	—
Signet × John Baer	—	—	—	22	—	—
Quebec 8	—	—	—	—	22	—
Quebec 5	—	—	—	—	21	—
Sioux (Neb. and Ore.)	—	—	—	—	—	21
John Baer	—	—	—	—	—	21
Hybrid 112	—	—	—	—	—	21
Abel	20	—	—	—	—	—
Bulmans Flat (Sd. 993)	—	—	23	15	—	—
Bulmans Special (Flat)	—	19	21	—	—	—
N.D.A.C.	18	—	—	—	—	—
Bison	17	—	—	—	—	—

In general, the ascorbic acid contents of the varieties recorded in Tables 7 and 8 compare favourably with the higher results for the same varieties reported in the literature. These high values are probably due in part to favourable climate with respect to temperature and light. Studies by Somers, Hamner and Nelson (15) and Hamner, Bernstein and Maynard (7) illustrate the important role played by climatic factors, particularly light intensity or amount of field (polar) illumination, especially for the 18 days prior to harvest, on the ascorbic acid content of tomatoes under field conditions. It is interesting to note from Table 6 that under conditions prevailing, there was no consistent difference in the ascorbic acid content of tomatoes harvested early and late in the season. This is also illustrated under commercial conditions in Table 9.

Truscott (18) has reported on the ascorbic acid content of some 80 tomato varieties grown in Ontario analysed over a 4-year period, 1940-43. Twelve varieties commonly grown for canning in that area showed ascorbic acid contents in the range of 15 to 38 mg. per 100 g. His data further indicate that while there was considerable variation even within a variety as affected by location and season, most of the tomatoes contained 20 mg. or more of ascorbic acid. This compares favourably with the information presented in Tables 6 and 7 for British Columbian tomatoes.

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* With few exceptions the figures given for each year are the average results of two or more pickings.

† Calculated to the nearest milligram by increasing 0·5 or over to the next milligram and dropping the decimal point below 0·5.

The production of a good quality, heavy yielding tomato with high vitamin C and satisfactory canning and juice characteristics appears to be a very urgent problem for the plant breeder. In this connection it is interesting to note that crosses made at the Summerland Station, using a high ascorbic acid variety as one parent, have given encouraging results, indicating the possibilities of developing a variety combining high ascorbic acid content with superior cultural and canning characteristics. Other investigators—Ellis and Hanmer (5), Lincoln, Zscheile, Porter, Kohler and Caldwell (9), Maclinn and Fellers (10), and Truscott (18)—have shown that not only ascorbic acid, but also the provitamin A (carotene) content of a variety tends to be an inherent characteristic of that strain or variety (genetic factors) and that tomatoes of increased ascorbic acid or carotene values may be developed by cross breeding. The genetic factor may at times be masked by environmental factors.

Ascorbic acid content of commercially canned juice and tomatoes

A comprehensive study of commercially canned tomato juice in Canada has revealed marked differences in ascorbic acid content between various brands and between different areas. The results of a survey of the ascorbic acid values of tomato juice and canned tomatoes as commercially produced are presented in Table 8. The most important points to note in this table are:

(*a*) The significantly higher average ascorbic acid content of 18·2 to 22·3 mg. for tomato juice manufactured in British Columbia compared with 13·0 to 14·2 for Quebec and 15·1 to 15·9 for Ontario.

(*b*) The relatively high minimum values of 12·6 to 15·6 mg. for tomato juice produced in British Columbia and the low minimum values of 6·1 to 9·8 mg. for Quebec and 4·3 to 8·6 mg. for Ontario juices.

(*c*) The minimum values for ascorbic acid in canned tomatoes are almost identical for all areas.

TABLE 8

ASCORBIC ACID CONTENT OF COMMERCIALLY CANNED TOMATO JUICE AND TOMATOES IN CANADA

Year packed	Area	No. of samples analysed	Ascorbic acid values per 100 ml. of juice		
			Average	Maximum	Minimum
Juice.			mg.	mg.	mg.
1941	British Columbia	18	22·3	33·3	12·6
1942	Eastern Canada	12	14·4	19·5	8·7
1944	Quebec	44	14·2	26·0	6·1
	Ontario	220	15·1	25·0	4·3
	British Columbia	54	19·8	26·9	15·6
1947	Quebec*	80	13·0	15·6	9·8
	Ontario*	556	15·9	21·5	8·6
	British Columbia	170	18·2	28·8	13·8
Tomatoes.			per 100 grams of tomatoes		
1940-41	British Columbia	39	21·6	32·4	14·4
1944	Quebec	5	15·9	18·9	14·1
	Ontario	30	17·2	20·3	15·1
	British Columbia	53	22·5	27·7	16·3

*Figures of Chemistry Division, Science Service, Ottawa.

A number of brands were consistently abnormally low. These results suggest that many of the low values for tomato juice are to a large extent due to faulty processing and unsatisfactory equipment, and not to the original raw material. This conclusion is substantiated by the ascorbic acid values presented in Tables 6 and 7 for numerous tomato varieties as grown in British Columbia, and by Truscott (18) for those grown in Ontario.

Comparison of ascorbic acid content of juice and tomatoes canned commercially

In order to compare the retention of ascorbic acid in tomato juice with that of tomatoes, the data in Table 9 were compiled. The factory from which the samples were secured was well equipped and considered to be packing both products satisfactorily. Under good processing conditions it would appear that on the average tomato juice contains about 14 per cent. less ascorbic acid than do comparable canned tomatoes. A limited survey of juice samples from a number of other factories indicates that losses much greater than this occur. Indications are that tomatoes lose very little ascorbic acid in canning. Unpublished data of the Chemistry Division, Science Service, Ottawa (1) and data presented by Truscott (18) and others show no significant loss of ascorbic acid in commercial canning of tomatoes.

Studies on retention of ascorbic acid in tomato juice under factory conditions

In 1943 studies were initiated on ascorbic acid retention under commercial conditions by following the produce as received at the factory through the various processing steps in the plant. This survey was carried out in one plant in 1943, certain recommendations then being made as to improvements in the manufacturing line. The study was repeated in 1944 and 1946 at the same factory as well as at two additional factories. The results of the study at Factory C in 1944 are given in Table 10. This factory has what is considered to be a very good tomato juice manufacturing line. A hot break of 190° F. to 200° F. is used. Salting tanks are also employed, but normally the juice remains in these tanks less than 10 minutes. Losses were in general smaller and less variable at this plant than in the other two plants investigated. The ascorbic acid figures recorded in Table 10 for raw fruit are very approximate due to the fact that only 12 to 16 fruits were analysed, whereas the other figures represent a volume of 50 to 100 gallons of juice or equivalent to around 700 to 1,400 lb. of tomatoes. It is unlikely that there was a significant loss at this plant in the hot break due to the few seconds only required to reach the inactivating temperature of 190° F. following milling. Hence this figure probably should be taken as representing more nearly the true average ascorbic acid value of the raw product being employed during the tests. On this basis the total loss in processing under good conditions was 2 to 3 mg. or 11·7 to 13·5 per cent. The per cent. loss or retention may be misleading as it varies with the quantity of ascorbic acid present, whereas the loss should be relatively constant at 2 to 3 mg. or less, irrespective of the amount of ascorbic acid originally present in the fruit. These results are in good agreement with those reported by Robinson, Stotz and Kertesz (12) who stated that under efficient manufacturing conditions tomato juice should contain at least 80 per cent. of the ascorbic acid content of the trimmed tomatoes. Loss at Factory A was only very slightly greater than at C, but Factory B showed a loss of 18·1 to 26·9 per cent. This was probably due to low temperature extraction with excessive holding time, allowing enzyme action together with aeration of the product. Losses greater than those found could be expected under such conditions, and these losses would be greater than at the other factories. None of the factories studied permitted contact of the product with copper equipment.

In studies made in 1946 at a factory employing a continuous juice line of the type recommended by the Summerland laboratory and "hot break" extraction, the process was found to have an apparent retention of over 90 per cent., the loss being less than 2 mg. per 100 g.

Effect of the method of extraction on the ascorbic acid content

All tests were made on the same lot of raw tomatoes. Pulping and preheating were carried out in a stainless steel jacketed kettle. Only stainless steel or inert metal equipment was

TABLE 9

ASCORBIC ACID CONTENT OF CANNED TOMATOES AND TOMATO JUICE PACKED ON SAME DAY AT FACTORY C

(1944 Season)

Sample No.	Date packed	Ascorbic acid content per 100 grams	
		Juice	Tomatoes
		mg.	mg.
1	Sept. 14	16·7	18·5
2	,, 15	21·3	24·3
3	,, 19	20·3	22·9
4	,, 21	15·2	27·7
5	,, 22	21·5	18·9
6	,, 23	17·2	21·1
7	,, 25	22·5	23·2
8	,, 26	22·5	17·8
9	,, 27	18·6	21·7
10	,, 28	20·2	24·3
11	,, 30	19·1	21·1
12	,, 30	19·3	—
13	Oct. 2	21·4	23·2
14	,, 3	23·5	27·1
15	,, 5	23·2	23·4
16	,, 6	17·2	23·2
17	,, 7	21·2	22·2
18	,, 11	20·1	22·2
19	,, 13	18·4	20·9
20	,, 16	18·1	19·8
21	,, 16	15·7	—
22	,, 17	26·1	31·6
23	,, 18	17·0	24·4
	Average ..	19·8	22·8
	Maximum ..	26·1	27·7
	Minimum ..	15·2	17·8

TABLE 10

RETENTION OF ASCORBIC ACID AT PROGRESSIVE STEPS IN COMMERCIAL PROCESSING OF TOMATO JUICE

Test No.	Steps in processing	Ascorbic acid per 100 g.
	FACTORY C (1944).	mg.
A 1	Raw tomatoes.	25·0
2	Emerging from hot break at 200° F.	22·2
3	In finisher receiving tank at 188-190° F.	20·7
4	Holding-salting tank (100 gal.) at 183° F.	19·4
5	After filler prior to sealing can at 182° F.	19·3
6	After canned juice stored three weeks.	19·2
B 1	Raw tomatoes.	20·8
2	Emerging from hot break at 200° F.	19·6
3	In finisher receiving tank at 188-190° F.	19·2
4	Holding-salting tank (100 gal.) at 183° F.	17·2
5	After canned juice stored three weeks.	17·3

employed. Cans were in all cases filled full at 190° F., sealed, processed 10 minutes at 212° F. and water-cooled. The results obtained by the different extractions may be accentuated over those obtained under commercial conditions due to somewhat greater time factors involved in the experiments.

The important point brought out in Table 11 is the necessity of rapid heating of the milled pulp to a sufficiently high temperature (at least 190° F.) to inactivate quickly the oxidase enzymes present in the tomatoes, and to pass in a few seconds through the temperature range of most rapid rate of vitamin C destruction. If this is done, loss of ascorbic acid is relatively small, but if not, the loss may be serious as indicated in Table 11 where as much as 36 per cent. loss occurred. The actual method of extraction appeared to be of little consequence provided the extraction was effected on pulp heated to 190° F. to 210° F. This temperature has the additional advantage that it also inactivates pectin-destroying enzymes, resulting in improved consistency of juice as pointed out by Kertesz and Loconti (8). Recently Clifcorn and Peterson (3) have reported that there is a rapid loss of ascorbic acid in tomato juice saturated with air, increasing directly with temperature up to 186° F.; with further increase in temperature a sudden drop in the rate of vitamin C destruction occurred. This is in general agreement with the writers' results. However, they found this loss to be due to some unknown factor other than enzyme, the rate of destruction being directly related to oxygen or air content and temperature of the juice.

TABLE 11

EFFECT OF THE METHOD OF EXTRACTION ON THE ASCORBIC ACID CONTENT OF EXPERIMENTALLY PREPARED CANNED JUICE

Test No.	Method of extraction	Ascorbic acid per 100 ml.	Per cent. loss compared to Lot K
		mg.	%
A.	Pulped and boiled 3 to 4 minutes. Extracted hot through screen.	30·2	8·5
B.	Pulped and boiled ½ to 1 minute. Extracted hot through screen.	29·6	10·3
C.	Pulped and heated to 173° F. Extracted hot through screen.	22·4	32·1
D.	Pulped and heated to 110° F. Extracted immediately.	22·9	30·6
E.	Scalded whole, 3 minutes in boiling water, pulped and extracted immediately through screen.	24·5	25·8
F.	Scalded whole, 2 minutes in flowing steam, pulped and extracted immediately through screen.	22·9	30·6
G.	Pulped and cold extracted through screen.	22·5	31·8
H.	Pulped and cold extracted through centrifugal juicer.	21·8	33·9
I.	Pulped and cold extracted through screw expeller press.	21·0	36·4
J.	Pulped and boiled ½ to 1 minute. Extracted hot through small centrifugal juicer.	25·2	23·6
K.	Pulped and boiled ½ to 1 minute. Extracted hot through small screw expeller press.	33·0	—

The oxidizing enzymes are located almost entirely in the skin (Wokes and Organ (19) and the Chemistry Division, Science Service, Ottawa (2)), very little being present in the juice or other tissue of the tomato. It would appear that steam blanching to inactivate the enzyme in the skin might be effective in reducing loss of ascorbic acid during extraction. However, it was found in experiments at the Summerland laboratory, where whole tomatoes were scalded in steam for 2 minutes or in boiling water for 3 minutes, that the losses in ascorbic acid were still 30·6 and 25·8 per cent. respectively (Table 11). By deducting 8·5 per cent. for screen extraction, net losses of 22·1 and 17·3 per cent. were encountered when compared with complete inactivation and screw expeller extraction. It would also appear from recent studies at the Summerland laboratory that tomatoes can be extracted cold in a commercial screw expeller juice machine with about the same loss as tomatoes extracted hot, *provided the juice is immediately heated in a matter of seconds to at least* 190° *F.*

Effect of sterilizing temperature and period

In Table 12 are presented the results of experiments to determine the effect of sterilizing temperature and period on ascorbic acid content of canned tomato juice. Each lot number represents a separate experiment ; thus (a) and (b) can be compared, but not one lot with another in respect to ascorbic acid content. Cans were filled full at 190° F. and after the heat treatment indicated were water cooled. The results show that the sterilizing temperature and length of cook had very little effect on the final ascorbic acid content of canned tomato juice. This is in agreement with limited data obtained in 1943 under commercial conditions. It was observed, however, that excessive processing temperatures with long processing time had a deleterious effect upon colour and flavour.

TABLE 12

EFFECT OF STERILIZING TEMPERATURE AND PERIOD ON ASCORBIC ACID CONTENT OF EXPERIMENTALLY CANNED TOMATO JUICE

Lot No.	Processing data		Ascorbic acid per 100 ml.
	Sterilizing process	Period	
		min.	mg.
1. (a)	210° F. (Boiling water.)	10	26·2
(b)	(Held on side in air.)	5	26·5
2. (a)	240° F. (Retort.)	10	26·6
(b)	210° F. (Boiling water.)	10	26·3
3. (a)	240° F. (Retort.)	20	27·9
(b)	210° F. (Boiling water.)	10	29·3
4. (a)	250° F. (Retort.)	5	24·9
(b)	210° F. (Boiling water.)	10	25·9
5. (a)	250° F. (Retort.)	15	26·8
(b)	210° F. (Boiling water.)	10	28·0

Effect of time and temperature of storage

Samples of tomato juice, some of which were fortified with ascorbic acid at the rate of 50 mg. per 100 ml., were packed in glass and cans and then stored at three different temperatures, 32° F., 55-60° F. and 65-80° F. Analyses were made at intervals of 7, 10, 16, 19 and 24 months. Insignificant loss occurred in all cases at 32° F. This loss never exceeded 5 per cent. even after 24 months' storage. Loss was greatest at the highest temperature range (65-80° F.), being 6 to 8 mg. per 100 ml. for unfortified, and 14 to 18 mg. for fortified, juice after 24 months' storage. This is a retention of at least 74 per cent. Approximately the same percentage of ascorbic acid was lost from both the unfortified and fortified juice. At the 55-60° F. range the loss of ascorbic acid was only about one half that at the higher temperature of 65-80° F.

Reduction of ascorbic acid during the first 7 months at all storage temperatures was negligible, being less than 1 mg. The rate of loss tended to increase thereafter, especially between the 10 and 16 months period.

While differences were small, the product packed in cans tended to retain the ascorbic acid slightly better than the bottled juice, allowance having been made for interference of reducing ions. No noticeable difference in colour or flavour was detected between the unfortified and fortified juice.

In summary of this study it may be concluded that tomato juice should retain after customary prevailing storage temperatures of 55-80° F. the following percentages of ascorbic acid: 98, 92, 81 and 74 per cent. after 7, 10, 16 and 24 months respectively.

These results agree in general with those of other investigators where storage conditions are comparable up to periods of 13 months. Fellers and Buck (6) reported the retention of ascorbic acid in glass-packed tomato juice stored at 70° F. to be about 86 per cent. after 6 months and 80 per cent. after 12 months. These authors also found most of the loss occurred in the first two or three months in storage which is not in agreement with the writers' results. On commercial samples stored at 40° F. and 78° F., Sale *et al.* (13) found storage losses at 12 months to be approximately 10 and 21 per cent. respectively. Cohee and Goodale (4) confirmed the writers' results that plain and fortified tomato juice (90 mg. ascorbic acid per 100 ml. added) lost approximately the same percentage of its ascorbic acid content during storage. These authors reported the retention to be 95·0 to 99·7 per cent., 80·3 to 89·4 per cent. and 49·7 to 51·9 per cent. after 3, 8 and 20 months at warehouse storage (40-95° F.) respectively. Their losses at 20 months' storage are much greater than those found by the writers.

Moschette, Hinman and Halliday (11) found no significant loss of ascorbic acid in canned tomato juice stored at 50° F. for 12 months. Retention at 65° F. was also good, being approximately 95 per cent. With 80° F., storage losses were greater, retention being 80 to 90 per cent., which is in agreement with results of the Summerland laboratory.

Composition of tomato juice canned in Canada

Table 13 gives the approximate composition of 346 samples of commercially canned tomato juice from the 1944 pack. These samples are segregated according to the production area. It will be noted that there is no significant difference in most constituents between the various sections of the country where tomato juice is packed commercially. The only marked difference due to area appears to be in the ascorbic acid content as shown in Table 13. Analyses at this laboratory and studies by Saywell and Cruess (14) and others indicate that the sugar in tomatoes or tomato juice is practically all reducing, the sucrose content normally being less than 0·05 per cent.

Limited studies on vitamin A content (carotene value) of British Columbia tomato juice after 9 months' storage at 60° F. indicate an extreme range of about 450 to 950 micrograms per 100 grams with an average figure of 740. Most values seem to fall between 600 and 800 micrograms with no apparent significant difference between commercial varieties grown in British Columbia. Seasonal and area variations have yet to be investigated. Vitamin A content of tomatoes appears to be well retained on processing. Also in general the loss of carotene during storage, even at relatively high temperatures of 80° F., is very small. The retention is about 95 per cent. after 12 months according to Fellers and Buck (6) and Moschette, Hinman and Halliday (11).

Grading of commercial tomato juice on basis of ascorbic acid retention

In order to obtain a basis on which to establish standards several hundred commercial samples were analysed for ascorbic acid. Fifteen milligrams has been discussed as a minimum content for Fancy quality, while 10 and 7·5 mg. have both been suggested for Choice quality. Table 14 shows the results of these analyses and indicates that a standard of not less than 10 mg. could be reasonably met for Choice quality.

TABLE 13

COMPOSITION OF COMMERCIAL TOMATO JUICE CANNED IN CANADA DURING 1944

Area	Refractive index*	Specific gravity†	pH	Constituents per cent. by weight.					
				Insoluble solids	Soluble solids*	Total solids	Sugar as invert	Total acid	Salt
				%	%	%	%	%	%
British Columbia									
Average	1·3423	1·028	4·28	0·78	6·3	6·55	3·33	0·462	0·59
Maximum ..	1·3459	1·039	4·41	1·04	8·6	8·92	4·09	0·773	1·35
Minimum ..	1·3408	1·023	4·12	0·56	5·2	5·49	2·31	0·244	0·08
No. of samples ..	66	66	64	47	66	62	60	64	64
Ontario									
Average	1·3423	1·028	4·20	0·61	6·3	6·49	3·19	0·443	0·72
Maximum ..	1·3452	1·037	4·42	0·98	8·2	8·48	4·49	0·583	1·43
Minimum ..	1·3401	1·021	4·02	0·53	4·8	4·88	1·99	0·326	0·09
No. of samples ..	232	232	232	167	232	232	218	232	232
Quebec									
Average	1·3424	1·028	4·21	0·73	6·3	6·58	3·32	0·446	0·67
Maximum ..	1·3447	1·035	4·38	0·95	7·9	8·05	4·04	0·578	1·50
Minimum ..	1·3409	1·022	4·06	0·54	5·0	5·33	2·61	0·345	0·14
No. of samples ..	48	48	48	32	48	48	44	48	48

* By refractometer at 20° C.

† Calculated from index of refraction at 20° C. according to Table 3, National Canners' Association Bul. No. 27-L, Revised 1941.

TABLE 14

PERCENTAGE OF SAMPLES OF COMMERCIALLY CANNED TOMATO JUICE IN RANGES THAT MAY BE USED AS GRADING STANDARDS

Province		Number of samples	Percentage over 15 mg.	Percentage less than 15 mg.	Percentage less than 10 mg.	Percentage less than 7·5 mg.
British Columbia—			%	%	%	%
	1944	54	100·0	0·0	0·0	0·0
	1947	170	94·1	5·9	0·0	0·0
Ontario—	1944	220	44·1	55·9	5·4	0·9
	1947	556	74·6	25·4	1·6	0·0
Quebec—	1944	43	58·1	41·9	16·3	9·3
	1947	80	6·3	93·7	5·0	0·0

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CHAPTER X

VITAMINS IN FRUIT JUICES AND RELATED PRODUCTS

By

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The realization that fruits may have a value in the diet far beyond that due to their content of carbohydrates and minerals is of comparatively recent origin and a comparison of the space accorded to vitamins in this publication and in the earlier bulletin of 1939 shows this to a remarkable degree. Fruit and fruit products have now come to be considered as a necessity for all classes of the population rather than as pleasant additions to the diet or, indeed, as luxuries beyond the reach of many. This tendency was seen in the years immediately preceding the war and received increasing impetus during the war years when the complete nutrition of the population became a matter of increasing urgency.

GENERAL REVIEW OF VITAMIN CONTENT OF FRUITS

In regarding fruits as valuable sources of vitamins, it is essential to retain a sense of proportion, lest undue claims be made on their behalf by the less critical. A list of the commoner fruits grown commercially is given in Table 15 with their general levels of the chief vitamins for which data are available. More detailed figures for apples and orange juice are given in Table 16. The figures have been derived from tables published by other workers (9, 12, 15, 27, 34), from the original literature and from unpublished figures. Points of special interest will be discussed more fully later with the appropriate references.

A comparison of the vitamin levels required by an average adult (derived mainly from the recommendations of the National Research Council (U.S.A.)) with ranges found in fruits as a whole, shows that they are pre-eminent as sources of ascorbic acid (vitamin C). Some fruits are poor in this constituent, but in general, the amount present is such that a large proportion of the daily requirement can readily be met by the consumption of a normal quantity of fruit. As sources of aneurin or of riboflavin, fruits are mainly comparatively poor and they can, at best, only supply a small proportion of the daily requirement. They do, however, make some contribution and many fruits contain sufficient aneurin for the metabolism of the carbohydrate they supply. When nicotinic acid is considered, the position again improves, for fruits are seen to contain very appreciable amounts of this substance. Of the common fruits, the banana, apricot, melon, the soft fruits, possibly the grape and particularly the tomato are seen to be valuable sources of nicotinic acid. The citrus fruits are also useful sources and in view of their wide consumption must be considered as of great importance. Among the less common fruits some are seen to be very excellent sources of nicotinic acid, e.g. the avocado, the custard apple, the mango and the guava.

Biotin is seen to be generally present but little information is available as to the contents of pyridoxine, folic acid and some of the other members of the " B complex ". Pantothenic acid is generally present, but the amounts are small compared with that estimated as being necessary for human nutrition. Vitamin D appears to be absent in fruits.

As suppliers of vitamin A, fruits again come into a position of some importance in view of their carotene content, for as shown in the Table, many are rich in this constituent. The range of values for any given fruit may, however, be very wide and only certain species or varieties show high figures. For example, it would be rash to assume the banana to be one of the best carotene sources, for only certain species (12) show the highest values ; the main bulk of the commercial supply probably gives values coming within the lower parts of the range.

TABLE 15

THE VITAMIN CONTENT OF FRUITS

(AS UNITS OF VITAMIN PER 100 GRAMS OF FRUIT)

	Vitamin C (Ascorbic acid) mg.	Aneurin (B_1) µg.	Riboflavin (B_2) µg.	Nicotinic acid mg.	Pantothenic acid mg.	Biotin µg.	Vitamin A (as carotene). I.U.
Daily requirement for average adult	30-75	1,200-2,000	1,600-2,600	12-15	10-12	—	5,000
Fruit							
Apple	1-35	20-60	5-50	0·05-0·1	0·05-0·2	0·25	40-100
Apricot	3-10	30	30	0·4-1·0	—	—	200-4,000
Avocado	12-33	70	100-200	0·8	0·25	10·0	300
Banana	5-18	30-50	20-50	0·5-0·8	—	—	30-3,000
Blackberry ..	20	—	35	0·2	0·23	0·5	300
Blackcurrant ..	90-360	40	60	0·3-0·4	0·40	2·5	30-100
Cherry	1-6	65	65	0·2-0·5	0·08	0·4-1·0	200
Custard apple ..	7	130	150	2·0	—	—	30
Date	0	—	40	0·4	—	—	30
Fig	4	50	50-300	0·2-0·4	—	—	200-1,000
Gooseberry ..	30-50	—	26	0·1-0·4	0·14-0·30	0·5	20-200
Grape	0·5-11	10-100	5-100	0·8	—	—	50
Grapefruit (juice) ..	30-50	30-100	10-40	0·2-0·5	0·12-0·17	0·3	10
Guava	19-1,160	40-60	20-40	1·2	—	—	2,000-5,000
Lemon (juice) ..	30-55	20-60	10-20	0·3-0·4	—	—	30-60
Mango	10-170	10-140	20-70	0·2-1·6	—	—	2,000-3,000
Melon	3-24	30	20	0·5-1·0	—	—	25-3,000
Orange (juice) ..	30-65	50-100	15-90	0·2	0·07-0·12	1·5	50-400
Papaya	27-136	20-60	30-50	0·2-0·8	—	—	1,000-3,000
Peach	2-12	10-70	10-50	0·4-0·8	0·04-0·07	0·2	400-2,000
Pear	1-6	10-100	40-150	0·1-0·4	0·02-0·05	0·1	10-20
Pineapple	10-40	50-125	20-80	0·2	0·10	—	40-300
Plum	4-7	50-200	40	0·2-0·5	0·12-0·24	0·0-0·1	100-400
Raspberry	20-30	20-30	35-70	0·4	0·26	2·0	50-300
Redcurrant ..	35-50	—	—	0·1	0·6	2·6	—
Rhubarb	9-24	10-25	—	—	—	—	30-100
Rose hip	10-4,800	—	—	0·4	0·4	0·3	10,000
Strawberry ..	30-65	20-60	30-70	0·3-0·5	0·07-0·23	1·2	70-700
Tangerine (juice) ..	18-37	100	30	0·2	—	—	—
Tomato	10-40	60	45	0·4-0·8	0·05-0·30	1·5	500-1,000

TABLE 16

AVERAGE CONTENT OF VITAMINS IN APPLES AND IN ORANGE JUICE

	Apple* (per 100 g. edible portion)	Orange Juice† (per 100 ml.)
Vitamin A	50-100 I.U.	280 I.U.
Aneurin	0·096 mg.	0·10 mg.
Riboflavin	0·05 ,,	0·09 ,,
Nicotinic acid	0·50 ,,	0·21 ,,
Pantothenic acid ..	0·03 ,,	0·07 ,,
Pyridoxine	0·026 ,,	0·085 ,,
Biotin	0·0009 ..	1·4 ..
Inositol	24·0 ,,	0·0047 .,
Vitamin C	1·0-20·0 ,,	53·0 ,,

* Taken from Esselen, Fellers and Gutowska (15).
† Taken from Californian Citrus Exchange (quoted by Charley (9)).

Some of the tropical fruits are seen to be excellent sources of carotene, e.g. the guava, mango and papaya, but among the common fruits the best sources are the apricot, the yellow-fleshed melons and peaches, the pumpkin, rose hips and tomato. Fraps (21) in a review of the carotene content of foodstuffs in 1947, calculated the cost of the daily requirement of vitamin A in terms of fruit and vegetable carotene. Taken as carrots, the daily 3 mg. of carotene could be obtained for about 1d., the same amount in orange juice would cost about 16s., and in the form of tomatoes 1s. 4d. It would thus appear that although many fruits may make a useful contribution to the daily supply of vitamin A only the tomato need be considered as one of the main fruit sources in most areas.

To summarize the position, fruits are of fundamental importance in supplying vitamin C: they also contribute valuable amounts of nicotinic acid, aneurin, biotin and carotene and supply small amounts of the other nutrients. Among the common fruits, citrus are seen to contribute especially ascorbic acid, nicotinic acid and some aneurin: the soft fruits ascorbic acid, nicotinic acid and biotin. The blackcurrant is outstandingly rich in ascorbic acid, and is at least the equal of the citrus fruits in the other respects. The tomato holds a special place as being a useful source of all the factors listed: although not rich in ascorbic acid, by reason of the amounts of the fruit (and its products) consumed it may supply an appreciable proportion of the daily requirement. In addition to its content of the members of the B Group in general, it also supplies vitamin A as carotene. The role of fruits in supplying vitamin C can hardly be over-emphasized, for they, together with vegetables, form the only important sources in the diet. In the form of fruit and of fruit products vitamin C is taken by all sections of the population and careful and controlled processing can ensure that the product reaches the consumer with the original vitamin content almost unimpaired. Fruits are of the greatest value in the " hungry months " of the year and for the nutrition of special classes of consumer, such as children, expectant mothers and invalids.

Before passing to a more detailed study of the vitamin levels in fruits and their products it should be pointed out that it is still not possible to make out an exact balance sheet for the nutritive value of any given foodstuff. Other factors present no doubt still await discovery and fruits (or other foods) which at first sight appear poor in vitamin content may yet be proved to play their part in a balanced diet.

NATURAL AND SYNTHETIC VITAMIN C

Following the above remarks, the possible presence of unknown accessory factors in fruits has given rise to considerable controversy as to whether synthetic ascorbic acid has the same value as that associated with fruits themselves. This question has been given point by the extensive work carried out on the factor known as vitamin P and a digression on this subject may be made at this point.

VITAMIN P

The question arose largely as a result of the original observation by Szent-Györgyi that fruits, in particular citrus, contained a flavanone, or group of such substances (" Citrin "), capable of increasing the capillary resistance in man and animals. This factor was considered necessary in addition to ascorbic acid in the prevention of scurvy. A detailed account of the ensuing controversy would be out of place here and reference may be made to the reviews of the subject, such as that by Munro, Lazarus and Bell (50) ; some of the more recent developments may, however, be briefly mentioned. The original contention that the symptoms of scurvy could only be relieved by a combination of ascorbic acid and vitamin P has been shown untenable, but the effect of the latter factor in increasing capillary resistance and decreasing the permeability of the capillary wall has been well substantiated. The work of Bacharach and of Scarborough and their collaborators (4, 66) has amply demonstrated the presence of such active substances in fruits and vegetables and their relative potencies are shown in Table 17.

TABLE 17

THE VITAMIN P ACTIVITY OF FRUITS AND FRUIT PRODUCTS

	Activity in Provisional Units per 100 g.	
	Clinical Assay (65)	Animal Assay (4)
Good Sources		
Grape (black or white)	500-1,000	—
Lemon : whole fruit	500	—
,, juice	500-750	450
,, peel	—	500
Orange : whole fruit	300-500	—
,, juice	300-600	500
,, peel	200-300	500
Blackcurrant	—	500-700
,, (purée)	200-300	500
Rose hips	—	300-600
,, syrup	500	350
Plum (blue)	100-200	—
Rowanberry	—	300
Moderate Sources		
Grapefruit (whole fruit)	100	—
Plum (Victoria : whole)	50-100	50
Cherry (whole fruit)	100	50-60
Blackberry (whole fruit)	80-100	60
Bilberry (whole fruit)	100	—
Poor Sources		
Apple (Bramley's Seedling)	—	60
Tomato	50	60-70
(Rhubarb)	—	(20)

The researches of Lavollay and his co-workers reviewed in recent publications (28, 34, 35) have made it clear that the capillary resistance can be increased by a wide range of substances, many of which far exceed in activity the original " Citrin ". Among these are flavone derivatives such as rutin, coumarin derivatives, poly-hydroxy phenols, even amino-acids, but among those showing the highest activity are epi-catechin, phloridzin and aesculetol (one microgram showing the effect in a guinea-pig). Ascorbic acid is itself active but in much diminished degree (1/10,000th) : nevertheless, Lavollay maintains that the lowered capillary resistance occurring in scurvy can be cured by ascorbic acid alone, although larger doses are needed. The function of the " Vitamin P's " appears to be that of inhibiting the inactivation of adrenaline in the tissues, a function shown to some degree by ascorbic acid itself ; it is apparently the adrenaline or a substance derived from it which maintains the resistance of the capillary wall and its impermeability to proteins.

It is therefore questionable whether such a group of widely diverse substances can legitimately be termed " Vitamin P ", especially since no definite case of avitaminosis P seems yet to have been forthcoming. It is, at the same time, apparent that this group of substances, of which some of the most active occur in fruits, can possibly play an important part in nutrition.

The richest sources of these substances are fruits and, as shown by the figures of Bacharach and of Scarborough, among the richest are grapes, citrus fruits, blackcurrants and plums (Table 17). The high vitamin P activity of blackcurrants has also been discussed elsewhere (54). Little work has been carried out on the stability of this factor and the figures for blackcurrant preparations show some discrepancies; the high activity of grape juices and wines would, however, suggest that it may be relatively stable (36).

Evidence for and against the suggestion that natural sources of ascorbic acid are superior to the synthetic product has been very conflicting, due in great part to the difficulty of obtaining basal diets free from fruits and vegetables and thus free from " co-vitamins " or from ascorbic acid stabilizers of the type described by Somogyi (74). The recent work of Melnick and co-workers (41) based on excretion studies shows no demonstrable difference between ascorbic acid derived from synthetic and natural sources. But in view of the work described in this and in earlier sections, there would still seem to be an advantage in deriving the normal requirements of ascorbic acid either from natural sources or from fortified natural sources which also supply other nutrient factors at the same time.

FRUITS AND THEIR LIQUID PRODUCTS AS SOURCES OF ASCORBIC ACID

Although fruits and fruit juices are to be looked upon as foods rather than merely as vehicles for supplying vitamins, most of those in common use do fulfil both purposes and it is therefore appropriate to discuss their various suitabilities for this latter purpose. At first sight it might be considered that as sources of ascorbic acid certain of the less common fruits provide far better raw material than, say, tomatoes, but the availability of the former is still very limited while the tomato products are already in large-scale commercial production. The different types of fruits may conveniently be listed as follows:

(*a*) Fruits produced commercially and already used for large-scale processing.

(*b*) Fruits processed for special purposes or in times of urgent need.

(*c*) Fruits awaiting further study and capable of fuller use in view of their special properties.

(*a*) Under the first heading come apples, citrus fruits, the soft fruits (blackcurrants, redcurrants, strawberries, raspberries, etc.) and tomatoes. These are all grown extensively for processing and their properties and treatment are described at length elsewhere in this and other chapters. The ascorbic acid contents of their freely expressed juices are listed in Table 18 (taken mainly from Charley (10)).

(*b*) The best example of a fruit processed under special conditions is furnished by the story of rose hip syrup. Although wild rose fruits were used to a limited extent on a domestic scale for many years, it was only during the recent war that their high ascorbic acid content became generally appreciated and when the production of syrups and powders as sources of ascorbic acid was undertaken in the U.K., Germany and the U.S.S.R. The investigation of wild rose species has shown that there is a very wide variation in the amount of ascorbic acid in the fruit. Pyke and Melville (60) in a survey of British and foreign species in 1942 found a close correlation between the latitudinal range of British rose species and their vitamin content, those from the Northern regions being much richer. For example, the Northern species ranged from about 1,000-1,200 mg. per cent. fresh weight, the intermediate group from 500-1,000 mg. per cent. and the Southern group from 250-500 mg. per cent. The foreign species (grown in Britain) showed, however, a much wider range from about 260 mg. to 4,800 mg. per cent., the highest value (i.e. 4·8 per cent.) being shown by Rosa Fedtschenkoa. Since that time many analyses of rose species have been made and the high values of many have been amply confirmed (e.g. 5, 8, 37). The species native to Northern Russia, Turkestan and Armenia appear

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Another fruit used to a limited extent as an emergency source of ascorbic acid is the fruit of the sea buckthorn (*Hippophaë rhamnoides*). According to the F.I.A.T. Final Report 179, this fruit (Sanddornbeere) was incorporated into vitaminized bars in Germany during the last war, but the methods of processing appear to have been wasteful of the vitamin originally present. The fruit was stated to contain from 180-800 mg. per cent. ascorbic acid. Other German sources (64) state that the higher figures are given by fruit from the more alpine regions (740-860 mg. per cent.), the fruit from coastal regions being lower in ascorbic acid (120-140 mg. per cent.). Norwegian workers (29) have reported intermediate figures (312 mg. per cent. in the juice) and they describe a 60 per cent. sugar syrup containing 137 mg. per cent. of ascorbic acid.

TABLE 18

ASCORBIC ACID IN FRUIT JUICES AND RELATED PRODUCTS

Juices.	Ascorbic acid (mg./100 ml.)
Blackcurrant	90-360
Orange	30-65
Grapefruit	37-50
Lemon	30-55
Lime	8-62
Tangerine	18-37
Strawberry	30-55
Raspberry	20-30
Tomato	16-33
Apple	2-34
Passion fruit	10-30
Redcurrant	35-50
Gooseberry	15-27
Loganberry	10-20
Plum	2-15
Cherry	2-5
Grape	1-3
Blackberry	Trace
Syrup :	
Blackcurrant	60
Concentrated syrups :	
Blackcurrant	350
Rose hip	200
Concentrated juices :	
Blackcurrant	700
Strawberry	150
Loganberry	125
Fruit powders :	
Blackcurrant	1,000-1,500 (/100 g.)
Rose hip	1,000-3,500 ,,
Orange	250-350 ,,

(*c*) Table 19 shows that there are many fruits, used as yet to a limited extent, which b reason of their high vitamin content might well be utilized more fully. Of those in commo cultivation, the guava appears to offer some promise. A study of many varieties was mad by Webber in California (79), who showed that although many were comparatively poor i ascorbic acid, others reached over 300 mg. per cent. Mustard (52) similarly found a wid range for common varieties (19-173 mg. per cent.), but found seedlings giving higher valu

(486 mg. per cent.). Still higher values were reported by Mrak (49), Waddington and Cist (77) and by Cruess and collaborators (13). Waddington and Cist describe the preparation of concentrates containing over 5 per cent. of ascorbic acid and the other authors describe, among other products, dehydrated preparations containing about 2 per cent. of ascorbic acid.

Some varieties of mango also appear rich in ascorbic acid (30, 51) and some contain very large amounts of carotene (1). Of the other fruits the jujube (62), the persimmon (24), and the West Indian cherries (*Malpighia* sp.) are of regional interest, one of the last mentioned containing 3 per cent. of ascorbic acid (2). The emblic (*Phyllanthus emblica*) has been reported as very rich in ascorbic acid, but some doubt has recently been thrown on this point (34, p. 44). The berries of the mountain ash (*Sorbus aucuparia*) contain appreciable amounts of ascorbic acid and of carotene (67) and according to Koernicke (32) the variety Moravica which is richer in ascorbic acid than the common species was deemed worthy of commercial planting in Germany during the war and its propagation is still being continued. The high ascorbic acid content of the fruit of *Actinidia chinensis* is of some interest (55, 61) as this climber has from time to time been considered suitable for growing commercially. Certain leaves of gladiolus (40) and a member of the primrose species (44) have been reported rich in ascorbic acid, and Russian workers at the V.L. Komarov Botanical Institute have found very considerable amounts in the leaves of many common trees. It is, however, as well to bear in mind that the high values reported for some of the lesser known sources may include other substances resembling, but not identical with, ascorbic acid (see above), and some of the figures must therefore still be treated with reserve.

TABLE 19

ASCORBIC ACID IN SOME LESSER KNOWN FRUITS

Fruit	Range in mg. %	Reference
Actinidia chinensis	200-300	(55, 61)
Guava	19-486	(52)
	49-319	(79)
	37-1,160	(77)
	164-971	(49)
Jujube	296-531	(62)
Malpighia glabra	957	(76)
Malpighia punicifolia ..	1,707-2,963	(2)
Mango	10-118	(51)
	33-171	(12)
Mountain Ash :		
(*Sorbus aucuparia*)	45-60	(66)
(,, var. *Moravica*) ..	103	(32)
Persimmon	7-277	(24)
Sea Buckthorn (*Hippophaë rhamnoides*)	120-860	(29, 73)

FACTORS INFLUENCING THE ASCORBIC ACID CONTENT OF FRUITS

It will be seen from the Tables 15 and 18 that the range of values for any one fruit can be considerable, and it is of interest to outline some of the factors which can give rise to such variations. If a juice is to contain the maximum possible amount of a vitamin it is an advantage to obtain raw material of high initial content. The factors given most study have been variety, cultural treatment and climatic conditions. The last factor is least within the control of the grower, but many workers have studied the effect of sunlight, temperature and rainfall on ascorbic acid production. The tomato has received much attention, but the results have been conflicting and, as pointed out elsewhere by the writer (56), while the difference noted between fruit grown with limited illumination (under glass or in shade) and in full sunlight is well established, the evidence that a high intensity of sunlight will invariably increase ascorbic acid production still further is much less certain. The wide variations in climate in different tomato growing areas of the globe are not reflected in corresponding differences in fruit composition.

(*a*) VARIETY

In the tomato, one of the main factors influencing ascorbic acid content is the variety, and many workers have shown that certain varieties have a tendency to high values and others to low values. This point is brought out more fully in Chapter IX. Similarly in other fruits, although a given variety may itself show wide variations, the effect of variety definitely influences the general ascorbic acid level. In a study of 308 strawberry varieties Slate and Robinson (73) found a range for ascorbic acid from 41-81 mg. per cent. while other workers (Dominion Experiment Station, Manitoba) found a range from 30 to 123 mg. per cent. in 48 varieties, the high value being given by a hybrid. As discussed earlier, the effect of species is shown to a remarkable extent by the rose family where the ascorbic acid in the fruit may vary from 10 mg. to about 5,000 mg. per cent.

The effects of variety, cultural treatment and season are clearly shown by tests carried out at Long Ashton on the blackcurrant. The effect of variety is of great importance in this fruit, grown largely for its ascorbic acid content, for although, as shown later, the varieties exhibit seasonal variations, they may be grouped into categories as in Table 20.

(*b*) MANURIAL TREATMENT

The effects of fertilizers and of season are shown by the figures in Table 21 (see also (7)). In these tests it was found that a high uptake of nitrogen by the bush was associated with a low ascorbic acid content in the fruit, but that at the same time the total yield of fruit (and of ascorbic acid) was increased. The Table gives the average figures for two varieties in three seasons, together with the maximum differences due to the different manurial treatments in those years. It is seen that the differences between the average values for the two varieties in the three years 1946, 1947 and 1948 were respectively 13·1, 29·0 and 34·2 mg.; these differences are in two years greater than the differences which could be produced by fertilizers. Furthermore, the effect of season (1947-1948) may be greater than the effect of variety or of fertilizers. One may thus conclude that as the seasonal effect cannot be avoided, and as manuring is required for the production of a high yield, the choice of variety is all-important in the blackcurrant.

TABLE 20

ASCORBIC ACID IN BLACKCURRANT VARIETIES

Variety	Range (mg./100 g.)
Baldwin	270-330
Westwick Choice Boskoop Blacksmith Black Tony *Seedlings :* BF–74 PS–24–1922 PS–24–2015 PS–D5–509	250-300
Cotswold Cross Seabrook Mendip Cross Westwick Triumph Davidson's Eight Wellington XXX Raven *Seedlings :* B.V.140 PS–24–2220 OP–21–3426	200-250
Edina Malvern Cross	90-150

TABLE 21

ASCORBIC ACID IN BLACKCURRANT MANURIAL TRIALS
(mg/100 g.)

Year	Cotswold Cross		Mendip Cross	
	Average	Maximum difference due to treatment	Average	Maximum difference due to treatment
1946	163·5	10·5	176·6	15·0
1947	141·1	27·2	170·1	13·0
1948	182·6	21·7	216·8	21·6

VITAMIN C CONTENT OF APPLE JUICES

The apple, by reason of its extensive use for juice production, is of special interest in this chapter. Having been long considered as poor in ascorbic acid it has now been the subject of fresh study and many varieties have been found good sources of the vitamin, although hitherto little has been found to pass into the juice. Work in many parts of the world has shown that the ascorbic acid content is very variable (3, 22, 23, 75), and most commercial varieties when they reach the consumer come within the range 5-10 mg. per cent. Some varieties show higher values, and work at Long Ashton has shown that some of the cider varieties appear consistently high (35 mg. per cent.) (57). The ascorbic acid content usually falls on storage, but some of those within the higher range show a good retention, e.g. Bramley's Seedling, Sturmer Pippin and Woolbrook Russet. It has been further shown that some of this latter class are capable of giving a juice containing appreciable amounts of ascorbic acid. In Table 22 are given figures for some freshly pressed apple juices (unpublished figures supplied by Dr. V. L. S. Charley and obtained in his laboratory), together with the range usually found for the fruit itself. Although in most varieties the juice contains little or no reduced ascorbic acid, in some the amounts are very considerable, especially in Calville Blanche, Woolbrook Russet and Brown Lees Russet. The amount in the apple juice is seen to bear no very direct relation to the amount present in the fruit; it is dependent on the rate of oxidation which takes place when the fruit tissues are ruptured. According to Geiger-Vifian (l.c.) the level of ascorbic acid in the apple and particularly in the stored fruit is dependent on the content of oxidative enzymes in the fruit and a similar observation has been made for the guava (30). In breeding for high ascorbic acid content it appears necessary to pay attention to the level of oxidizing enzymes in the parents rather than to the level of ascorbic acid.

TABLE 22

ASCORBIC ACID IN APPLES AND THEIR RESPECTIVE JUICES

Variety	Ascorbic acid in whole fruit. mg./100 g.*	Ascorbic acid in freshly pressed juice. mg./100 ml.
Blenheim	6·3-18·4	2·7-6·5
Bramley's Seedling	18·1-22·3	0·0-17·0
Brown Lees Russet	—	27·0
Calville Blanche	—	31·6
Crawley Beauty	11·2-11·8	0·0-1·3
Edward VII	8·5-13·6	1·9
Lane's Prince Albert	15·4	0·2-2·0
Laxton's Superb	5·0-13·9	0·0-2·2
Newton Wonder	10·4	0·0
Worcester Pearmain	16·0	0·0-2·0
Woolbrook Russet	28·5	16·2-34·0

* Taken from Long Ashton figures (57).

Under present-day processing methods and with the varieties at present in use, apple juice can thus only be expected to contain very small amounts of ascorbic acid. But in view of its wide-scale production apple juice is a most suitable vehicle for fortification with ascorbic acid to enhance the value of its other constituents.

Citrus Fruits

The citrus fruits as sources of ascorbic acid are of the greatest economic importance and the general levels reported for orange, grapefruit and lemon juices are indicated in Tables 15 and 18. Wide ranges for the ascorbic acid content of orange and grapefruit juices have been reported, for example, 32-66 mg. per cent. for the former and 25-50 mg. per cent. for the latter, but in the main commercial varieties the ranges would appear to be usually much less. Metcalfe *et al.* (42) who reviewed the literature on the subject found that the differences due to location were often greater than the differences between the varieties studied; taken as a whole, however, there was no consistent difference between fruit from Texas, California or Florida. Grapefruit juice varied less than orange juice, but was always rather lower in ascorbic acid. Floyd and Fraps (20) found a major variation in the ascorbic acid content of grapefruit juice due to the condition of the fruit, a large proportion of stored culls giving a lower value. For example, a batch containing only 10 per cent. of culls gave a figure of 36·1 mg. per cent. while one consisting mainly of culls registered only 29·5 mg. per cent. In a wide study of processing operations in factories in California and Arizona, Lamb (33) found that in those fruit-growing regions the values for orange and grapefruit juice lay within the ranges 40-54 mg. per cent. and 40-47 mg. per cent. respectively.

FACTORS AFFECTING THE STABILITY OF VITAMINS IN FRUIT JUICES

Ascorbic Acid

The stability of ascorbic acid in fruit products is intimately bound up with the general stability of the product as a whole, for severe losses during processing or in storage are generally accompanied by deleterious changes in colour, flavour and appearance. The amount of ascorbic acid retained in a juice has indeed been considered as a suitable criterion for judging quality as a whole (cf. tomato, p. 121).

In fruit juice processing it soon becomes evident that the stability of ascorbic acid is to a large extent a property of the fruit itself; thus in citrus and blackcurrant processing it is remarkably stable, while in the apple ascorbic acid is so unstable that little usually appears in the freshly pressed juice. The degree of stability appears to depend upon a number of factors including the pH, the presence of oxidizing enzymes or of enzyme inhibitors and the availability of other oxidizable substances capable of assisting in the oxidation of ascorbic acid. There appears to be a balance of factors, for the destruction of oxidizing enzymes by heat may at the same time destroy an oxidation inhibitor. The fact that ascorbic acid shows a greater stability in pasteurized apple juice than in water (Melnick *et al.* (41)) suggests that an inhibitor is present even though in fresh apple juice it is overwhelmed by the oxidizing system. The same authors showed that in fresh orange juice ascorbic acid is even more stable, in this juice the inhibitor preponderating over the oxidizing system. The observation that ascorbic acid is more stable in fresh orange juice than after pasteurization (71) suggests that the inhibitory mechanism is unstable to heat and thus the pasteurization of juices may be only a partial safeguard against subsequent loss. This is in agreement with the findings of Somogyi (74) who has investigated the relative stability of ascorbic acid in fruits and vegetables. The stability is found to depend on the balance between the oxidizing mechanisms and an oxidation inhibitor; the latter, which is unstable to heat, being found in the greatest amounts in the citrus fruits.

In addition to the factors inherent in the nature of the raw material itself there are others more directly dependent on methods of processing. The catalytic effects of copper on the oxidation of ascorbic acid are sufficiently well known to make any lengthy discussion unnecessary.

The amounts of copper which are required to produce an appreciable loss of ascorbic acid are extremely small; for example, the rate of loss of ascorbic acid in water distilled from a metal still may far exceed that in water purified by careful distillation in glass. It is, therefore, of the greatest importance to avoid such metallic contamination during processing operations.

As the oxidation of ascorbic acid by any of the above mechanisms is ultimately dependent on the presence of oxygen, the avoidance of undue exposure to air or excessive aeration gives some control. De-aeration can remove dissolved oxygen from the body of the liquid, but if the final product is bottled with an appreciable air space some eventual oxidation is to be expected.

The competitive removal of oxygen by the addition of other oxidizable substances has been used empirically for many years by the addition of sulphur dioxide. The improved retention of ascorbic acid in soft fruit juices and syrups following the use of sulphur dioxide was shown by the early work at Long Ashton (72, see also p. 167). Other substances have been tested for this purpose, such as cysteine (58) and thiourea (34, p. 31), but their use is restricted by legislation and by health considerations. A more promising line is the suggested utilization of D-iso-ascorbic acid, which possesses similar oxidation-reduction properties to the ordinary L-ascorbic acid, but has only one-twentieth of its biological activity.

The addition of D-iso-ascorbic acid to tomato juice and to grape juice fortified with L-ascorbic acid has been reported as preventing the oxidation of the more biologically useful L-ascorbic acid (16). Added to grape juice fortified at the rate of 50 mg. per cent. with L-ascorbic acid the D-isomer (20 mg. per cent.) prevented losses during processing and storage. At the lower rate of 6 mg. per cent. the D-isomer protected tomato juice against L-ascorbic acid losses even under adverse processing conditions. In higher concentrations the D-isomer improved colour and flavour and the processed (heated) juice more nearly resembled freshly pressed tomato juice. The results are presented in Table 23, quoted from the original paper.

TABLE 23

THE EFFECT OF D-ISO-ASCORBIC ACID AS AN ANTIOXIDANT

Original ascorbic acid (mg./100 ml.)		After 7 months at room temperature			After 5 months at 49° C.		
L-	D-iso	Loss of L- (%)	Flavour	Colour	Loss of L- (%)	Flavour	Colour
21·0	0·0	26·0	good	good	23·8	off	browned
21·0	6·0	0·0	,,	,,	10·5	good	good
21·0	18·0	0·0	fresh	,,	0·0	fresh	,,

The effects of the factors outlined above will be further brought out in the discussion of the different types of product, but the general requirements for the preservation of ascorbic acid may be summarized here and they are essentially as given by Charley (10):

(1) immediate inactivation of enzyme systems in the fruit at the commencement of processing;
(2) de-aeration where possible;
(3) avoidance of contact with air at every stage of manufacture;
(4) avoidance of contact of fruit or juice with copper;
(5) efficient pasteurization and filling of bottles under aseptic and anaerobic conditions;
(6) use of sulphur dioxide if chemical preservation is necessary.

OTHER VITAMINS

Compared with the data published for ascorbic acid, the amount of information on the stability of the other vitamins in fruit products is scanty. Carotene changes have been studied mainly in regard to the stability in tomato products and this aspect receives attention in Chapter IX. In general terms its stability is bound up with the avoidance of oxidation, especially in the presence of light. Of the B Group of vitamins aneurin is sensitive to heat and would be expected to suffer during many processing operations ; for example, a 30 per cent. loss of aneurin has been reported for apples on cooking. Aneurin is also sensitive to sulphur dioxide, and this point is of considerable importance in view of the widespread use of this preservative. Riboflavin, nicotinic acid, pantothenic acid, folic acid, biotin and pyridoxin are heat stable, but riboflavin is sensitive to light and is destroyed by direct illumination. Its retention would therefore be expected to be related to the conditions of storage of the final product. The behaviour of these vitamins in fruit products will be indicated in the later discussion of the different types of product.

THE RETENTION OF VITAMINS IN FRUIT JUICES DURING PROCESSING AND STORAGE

The war-time researches on the dehydration of fruits and vegetables drew attention to certain complications which may arise in the estimation of ascorbic acid in processed foods, and it was shown by Mapson (38) and by Wokes (80) that heated or long stored products may contain reductones or other similar substances interfering in the estimation of the vitamin and giving rise to erroneously high values. Most fresh fruits and vegetables are free from these substances and in their analysis the difficulty does not arise ; the point should, however, be considered when new products of fruits or products stored under adverse conditions are being studied.

Products which have been subjected to prolonged heating or stored at high temperatures are the most likely to contain such interfering substances, and work at Long Ashton (58, 59) has shown that juices, syrups and concentrates stored under conditions which promote oxidation can contain appreciable amounts of such substances. In fresh fruits and juices or in normally stored syrups the amounts were small or non-existent, but a small amount of interference has always been found in blackcurrant analyses which was associated with substances present in the skin of the fruit. Other work at Long Ashton (11) has shown that in jams the true ascorbic acid may be much less than that given by direct titration and this has also been shown by Miller (43) who studied a wide range of honeys, jams and fruit products. This author found that reductone interference was associated with deleterious quality changes and occurred to some extent when citrus concentrates or powders were stored in the presence of air. Interference was most marked in products originally poor in ascorbic acid.

It is thus evident that the results of storage tests on products at the higher temperatures or under adverse storage conditions must be treated with some caution unless the possible presence of interfering substances is taken into account in the analysis : otherwise the observed retention of ascorbic acid may be in excess of the true value.

(*a*) Blackcurrant Products

Of the English soft fruits, the blackcurrant is of chief commercial importance in juice processing and, being used primarily as a source of ascorbic acid, the stability of the product is of particular interest. The bulk of the fruit is processed at the time of picking, but some part of the crop is canned for processing at the end of the season. Sulphiting has not been used to any considerable extent, but the possibility of this form of preservation has been considered by Kendrick and Downer (31), who found that the loss of ascorbic acid in the sulphited fruit was of the order of 2 per cent. per month.

The losses encountered in processing fresh fruit to syrup on the commercial scale are, according to Dr. V. L. S. Charley (private communication) largely dependent on the time taken during the operations themselves. Any difficulties in manipulation during processing resulting in greater exposure to air are followed by lower vitamin values in the juices. Centrifuging can, however, be carried out with practically negligible loss. If the final syrup is pasteurized in bottle this results in a loss of no more than 1 to 2 mg. per cent. The overall retention of ascorbic acid during processing from fruit to syrup may be taken as from 80-90 per cent.

In the early work on blackcurrant processing it was found that the ascorbic acid in the juice was far less stable than in the final syrup. It is now found, however, that if the juice is held under pressure storage the retention of ascorbic acid is satisfactory, especially if the temperature is maintained slightly above freezing point. Under these conditions approximately 5 per cent. of the initial ascorbic acid is lost in the first three months and thereafter the change is negligible.

Some of the factors influencing the stability of ascorbic acid in the final syrup were studied in the earlier work on blackcurrant processing when it was found that preservation with sulphur dioxide gave a better retention than did either pasteurization alone or preservation with sodium benzoate (72). The favourable effect of sulphur dioxide was ascribed to its action in restricting oxidation due to air dissolved in the liquid or present in the head-space of the container. Later work on blackcurrant syrups (59) showed a definite relation between the loss of ascorbic acid and the amount of available oxygen in the container. The percentage retentions in an experimental syrup bottled anaerobically or with different amounts of air space are shown in Table 24. It will be seen that there was little difference in the retention in series (b) and (c) where the sulphur dioxide was capable of reducing all the oxygen in the head-space, while in series (d) where the sulphur dioxide was only sufficient to reduce about half of the available oxygen, the retention at the end of the period was only about one third of that in the other two. In the de-aerated syrup (a) filled under carbon dioxide the retention was slightly better after 18 months than in series (b) with a very small head-space. In present-day commercial processing the losses of ascorbic acid in the finished syrup are below the figures quoted and amount to about 5-10 per cent. over a storage period of one year.

TABLE 24

PERCENTAGE RETENTION OF ASCORBIC ACID IN BLACKCURRANT SYRUP ON STORAGE

Conditions of bottling	After 5 months	After 9 months	After 18 months
(a) De-aerated, CO_2-filled head space ..	98·1	89·0	78·6
(b) Normal, no head space	96·1	91·0	74·9
(c) Normal, small head space	92·6	88·4	72·5
(d) Normal, large head space	68·2	59·9	27·3

(*b*) ROSE HIP SYRUP

The ascorbic acid in rose hip processing shows a rather lower stability than in blackcurrants and the preliminary work on the subject showed the need for careful control of all processing operations. The details of rose hip syrup processing have been mentioned in Chapter VII and only the figures for ascorbic acid retention will be summarized here (Dr. V. L. S. Charley, private communication). The initial ascorbic acid level of the fruit will depend on its origin (p. 112) and condition. The maximum loss during the enzyming of the bulked extract is 10 per cent., but this may be much lower (2 per cent.) if the fruit is of good quality and processing proceeds smoothly. During the concentration of the extract, the material may lose up to 8 per cent. of its ascorbic acid and a further 8 per cent. may disappear during the syruping operation. If, however, the sugar is incorporated in the extract before the evaporation this secondary loss can be largely avoided. The total loss would therefore appear, on the average, to lie between 15 and 20 per cent.

The retention of ascorbic acid in the syrup itself is variable and depends on the methods of processing which have been adopted. Generally speaking, the retention over a period of 6-12 months is about 80 per cent. of that present when the syrup is bottled.

(*c*) TOMATO JUICE

The factors governing the stability and retention of ascorbic acid in tomato juice are described in Chapter IX, where it is shown that under good conditions of processing and storage the losses need only be small. Of the other vitamins present, those which have been studied are carotene, aneurin, riboflavin and nicotinic acid and, as stated earlier (pp. 125, 126), these vitamins are of particular importance in this product as their all-round levels are higher than in most juices. From the Canadian work described in Chapter IX, carotene appears stable in tomato juice and Moschette *et al.* (47) state that no loss was found in their stored canned juices after one year at 50°, 65° or 80° F. A greater loss of 15 per cent. was noted by Fellers and Buck (19) for bottled juice kept for one year in subdued light and they found that amber glass gave a better retention than flint glass.

Moschette *et al.* also studied the stability of aneurin, riboflavin and nicotinic acid in tomato juice. They found no loss of nicotinic acid at a variety of temperatures, but a loss of riboflavin (about 20 per cent.) at the same temperatures. Aneurin was stable for 8 months at 50° and 65° F., but showed a possible slight loss after one year. There was a definite loss at 80° F. increasing with time as shown :

4 months	..	91	per cent.	retained.
8 ,,	..	87	,,	,,
12 ,,	..	82	,,	,,

Under warehouse conditions of storage the retentions were 79 per cent. at 77° F. and 96 per cent. at 58° F.

Tomato juice thus shows, under normal conditions, an excellent retention of ascorbic acid, carotene and nicotinic acid, i.e. in the vitamins for which it is particularly valuable.

(*d*) CITRUS JUICES

Stability during processing. Detailed reviews of the present-day methods of citrus juice processing have appeared in the literature (e.g. 33, 70) which supplement the earlier work on the subject. Losses of ascorbic acid during the actual processing operations are small provided metal catalysts are excluded and, according to several teams of workers (45, 65, 70) they need not exceed 3 per cent. Floyd and Fraps in 1942 (20) quoted losses which exceed this and in a survey of factories found that the time elapsing before pasteurization was of chief importance. Wagner *et al.* (78) in another survey found the average retention during canning operations to be 96·5 per cent. with a range from 92·2 to 99·8 per cent., the low values in these tests being where the hot juice was held for excessively long periods after pasteurization. Lamb (33) found an over-all retention of 98 per cent. in numerous factories in California and Arizona : the lowest figures were 94·4 per cent. for orange juice and 91·6 per cent. for grapefruit juice. This author reports a higher stability for citrus juices than that suggested by Floyd and Fraps (20) and is in agreement with Evenden and Marsh (18) who studied temperature effects with a view to low temperature preservation of orange juice (q.v. below).

Stability on storage. In a comparison of orange and grapefruit juices, Lamb (33) found that the former was the less stable in the early stages of storage, but that the rate of oxidation of ascorbic acid in the two juices became equalized later and was of the order of 1 per cent. per month at 70° F. Moschette *et al.* (47) found similar losses at this temperature, viz. about 15 per cent. in one year. At 80° F. the loss was from 23-27 per cent., a figure in agreement with that found by Ross (63). The effects of time and temperature are shown by the figures below (quoted from Moschette *et al.*) :

Temperature °F.	% retention of ascorbic acid in grape-fruit juice		
	4 months	8 months	12 months
98	75	54	31
80	88	79	75
65	91	91	90

At the lowest temperature the loss of ascorbic acid is small and increases slowly with time of storage ; at the higher temperatures the rate of loss is increasingly rapid. This is in agreement with Ross, who found that the rate of loss doubled for every 10° rise of temperature between 10 and 27° C. (50 and 81° F.), but quadrupled over the range 27-37° C. (81-99° F.).

Rather higher rates of loss were noted by Sale and collaborators (65) in a factory study of orange and grapefruit juices. Their figures for the retention during processing (98 per cent.) are similar to those of the other workers, but the percentage retentions after storage at room temperature are lower :

Juice	Months' storage at room temperature. % retention			
	3	6	9	12
Grapefruit	94·5	85·4	78·7	73·1
Orange	92·5	85·3	80·1	75·0
Blend	93·3	86·1	77·9	72·2

The work of Evenden and Marsh (18) is of particular interest in that they studied the possibility of distributing orange juice by bulk shipment under refrigerated storage and using preservatives to keep down the microbial count. Straight juices and de-aerated juices were stored at 3°, 32°, 50° and 77° F. and the effects of preservatives were studied. At the lower temperatures the losses of ascorbic acid were small enough to permit retail distribution. The problem of distribution in this manner appeared, however, to be less a question of ascorbic acid loss than of flocculation in the juice due to the action of pectic enzymes which remained active in the unpasteurized juice.

The stability of aneurin in orange juice (and in other juices) was also studied by Moschette *et al.* (47) and the results are given in tabular form below :

Orange Juice

Storage temperature °F.	% retention of aneurin after 1 year
80	89
65	98
50	100

Grapefruit Juice

Storage temperature °F.	% retention of aneurin after		
	4 months	8 months	12 months
98	75	54	31
80	88	79	75
70	—	—	85
65	91	91	90

Thus in these juices (as in tomato juice) aneurin is stable at temperatures around 50°-65° F., but shows a definite loss at the higher temperatures ; in orange juice the retention is slightly better than in grapefruit juice. Under warehouse conditions the losses of aneurin in orange juice were apparently negligible up to one year (0-5 per cent.).

Concentrates and Powders. The newer developments in the dehydration of citrus juices (25, 46, 68, 69) raise the question of the stability of ascorbic acid in products of this nature. In juices partially concentrated for the purpose of quality standardization the stability of ascorbic acid was found equal to that in the fresh juice (46), and after 6 months' storage at 40° and 80° F.

the amounts retained were 97 per cent. and 88-89 per cent. respectively. In another series of tests by Curl (14), vitamin C in orange juices of 13-71 per cent. soluble solids was found to be stable for one year at 40° F., but at higher temperatures (80, 100 and 120° F.) the rate of deterioration increased with increasing concentration. The concentrated products in the tests of Hayes *et al.* (25) showed a similar stability, concentrates of 50-60 per cent. soluble solids showing a retention of 96·6 per cent.: the powder obtained by vacuum drying showed a retention of 99·2 per cent. after 6 months at 80° F. Later developments by these workers on a larger scale have been stated to confirm these findings and the stability of ascorbic acid in the powder at temperatures below 40° C. (104° F.) was found satisfactory (see also Miller (43)).

ASCORBIC ACID IN FORTIFIED JUICES

The fortification of juices with added ascorbic acid has been applied for two main reasons—to increase the vitamin content of juices normally poor or lacking in ascorbic acid or to improve the quality of the product as a whole. A more specialized instance is the use of the less biologically active D-iso-ascorbic acid as an anti-oxidant to protect the more valuable L-ascorbic acid. The technical aspects of the fortification of apple and grape juices, normally lacking in ascorbic acid, are discussed in Chapter III: in this section only more general aspects will be mentioned.

The addition of ascorbic acid to apples at the time of milling (Chapter III, pp. 49, 52) has been used to improve flavour rather than to fortify the juice, the oxidative changes normally taking place being delayed until the added ascorbic acid is oxidized. In effect the time available for processing is lengthened and the juice can be stabilized by heat before the fresh apple flavour has been lost.

In fortification proper, it is desired to stabilize the added ascorbic acid either to increase the nutritional value of the product or to improve its colour, flavour and other quality characters. The pros and cons of fortification in general have been discussed by Marshall (39) and by Heller *et al.* (26) who carried out surveys of apple juices manufactured in the U.S.A. Opinions on the flavour ratings of fortified and unfortified juices appear to be varied and according to these authors the loss in flavour following de-aeration (with loss of volatile constituents) may offset the gain said to follow the addition of ascorbic acid. Heller *et al.* report no definite relation between flavour rating and fortification, but Esselen *et al.* (17) record a definite improvement in flavour and colour. That fortification of apple juice can give an improvement in general quality also appears evident from the work of Pederson and co-workers (53) who showed that the addition of ascorbic acid slowed down the darkening of stored apple juices. These workers showed that the stability of the added ascorbic acid was related to the type of juice and that its behaviour in apple juice was not necessarily followed in other juices. In apple juice the colour changes were found to be related to direct oxidation, but in other soft-fruit juices the colour changes appeared due to mutual reactions between the juice constituents. In apple-cherry juice mixtures the addition of ascorbic acid gave some protection against deleterious colour changes, but in apple-raspberry juice mixtures this was not so. In strawberry juices, which rapidly lose their red colour and fresh flavour, the loss of colour was found to be associated with the presence of ascorbic acid and fortification accelerated the change, although subsequent browning was inhibited.

The fortification of some other juices is discussed by Esselen and co-workers (17) who carried out the fortification of apple, cranberry and grape juices and studied the effect on flavour and colour and the ascorbic acid retention. At the rate of 50 mg./100 ml. the colour of apple juice was lightened and the flavour improved and an effect was also noted at the lower rate of 20 mg./100 ml. (L- or D-iso-ascorbic acid addition). In cranberry juice, darkening was retarded, but there was no effect on flavour. The more stable grape juice showed little effect on colour and no flavour change following fortification. The retention of ascorbic acid appeared rather better in the cranberry juice than in the apple or grape juices, but it was concluded that the addition at the rate of 50 mg./100 ml. should ensure that each juice contains at least 35 mg. after normal distribution to the consumer.

Reference has already been made to the use of the D-iso-ascorbic acid as an antioxidant (p. 135) for the preservation of the ascorbic acid present normally in tomato juice. Its use for the protection of added ascorbic acid in grape juice is also described by these authors (Esselen *et al.* (16)), and the table below is derived from that paper :

EFFECT OF D-ISO-ASCORBIC ACID ON THE STABILITY OF ADDED L-ASCORBIC ACID IN BOTTLED GRAPE JUICE DURING PROCESSING AND STORAGE

Original ascorbic acid		8 months storage at 23·9 - 26·7° C.		
L-	D-iso-	L-	D-iso-	Loss of L-(%)
0·0	0·0	0·0	0·0	—
50·0	0·0	36·0	0·0	28·0
50·0	20·0	50·0	1·0	0·0

In the juice fortified only with L-ascorbic acid storage for 8 months produced a loss of 28 per cent. which would be eliminated by the addition of the more readily oxidized D-iso-compound at the rate of 20 mg./100 ml.

The fortification of solid fruit products has been largely studied in relation to the war-time needs of the armed forces. The suitabilities of different types of food products as carriers have been studied by Moyer (48) and by Brenner *et al.* (6), the latter workers testing a wide variety of products. In the tests of Moyer, apple and carrot juice concentrates were fortified with ascorbic acid over a range of levels between 3 and 30 mg. per g. The stability on storage appeared much the same in both types of product and the percentage retention was not influenced by the degree of fortification. The retention of ascorbic acid was mainly dependent on the temperature of storage : at temperatures between 32° and 73° F. losses were slight over a period of 8 months. At 98° F. the losses were greater after only 2 to 3 months' storage (over 20 per cent.) and at 113° F. they were still more serious. It was concluded that storage for any length of time should be carried out under refrigeration.

The effect of temperature on ascorbic acid stability in solid carriers was also brought out in the work of Brenner *et al.* (6), although most of their tests were carried out over the higher temperature ranges. Other factors such as moisture content, acidity and permeability were, however, also found to play some part. The fruit products tested were mainly dehydrated orange juices, orange juice bases and jams which were fortified with ascorbic acid or, in a few instances, with guava products. The products stored at low temperatures (—3 to +40° F.) showed good retentions on storage, but under the more severe conditions usually applied the fruit bases showed severe losses. Unfortified orange juices and powders showed negligible losses after 6 months at room temperature but at 100° F. the losses varied from about 40 to 60 per cent. ; in some fortified orange beverage bases the losses were even more severe. It thus appears evident that temperature of storage is all-important in solid products of this type, especially when they are porous and given access to air and moisture.

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CHAPTER XI

PECTIN DEGRADING ENZYMES AND THEIR IMPLICATION IN THE FRUIT PRODUCTS INDUSTRY

By

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INTRODUCTION

In the technology of fruit products, pectin degrading enzymes are of importance from two separate aspects. In the first of these, the naturally occurring pectic enzymes of the fruit may, during processing, degrade the pectin present with a loss of texture and appearance of the finished product (e.g. tomato and citrus products). In such cases the details of processing must be modified to reduce enzyme action to a low level, and it is therefore desirable that some of the properties of the natural pectic enzymes, including their pH activity range, heat stability, and so on should be known. The other aspect concerns the production of fruit juices and related products where pectin degrading enzymes (usually produced from " moulds ") are added during processing to produce bright juices of low viscosity which filter easily and do not deposit a pectin precipitate on storage. To obtain the best results in processing for both these branches of fruit technology, fundamental data on the mode of action of the pectic enzymes is of the utmost value.

(a) The action of pectin degrading enzymes on pectin

Research into the structure of pectic substances and the action thereon of the appropriate enzymes has advanced considerably in the past few years. Valuable contributions on the chemistry of the pectic substances have been made by European and American workers, but the bulk of the fundamental work on the pectic enzymes has come from the U.S.A.

In 1936 Z. I. Kertesz (50) reviewed the pectic enzymes in the light of the data then available, and more recently Phaff and Joslyn (47, 48) have reviewed both the chemistry of the pectic substances (47) and the latest work on pectic enzymes (48). Reviews of the chemistry of pectin with some data on points relevant to fruit products have also appeared (8, 87). It is not possible in the space available to discuss the present status of pectin structure and pectic enzymes in detail, and the reader is referred to the original papers and the above-mentioned references for further details. The reviews of Phaff and Joslyn have excellent bibliographies and are to be recommended.

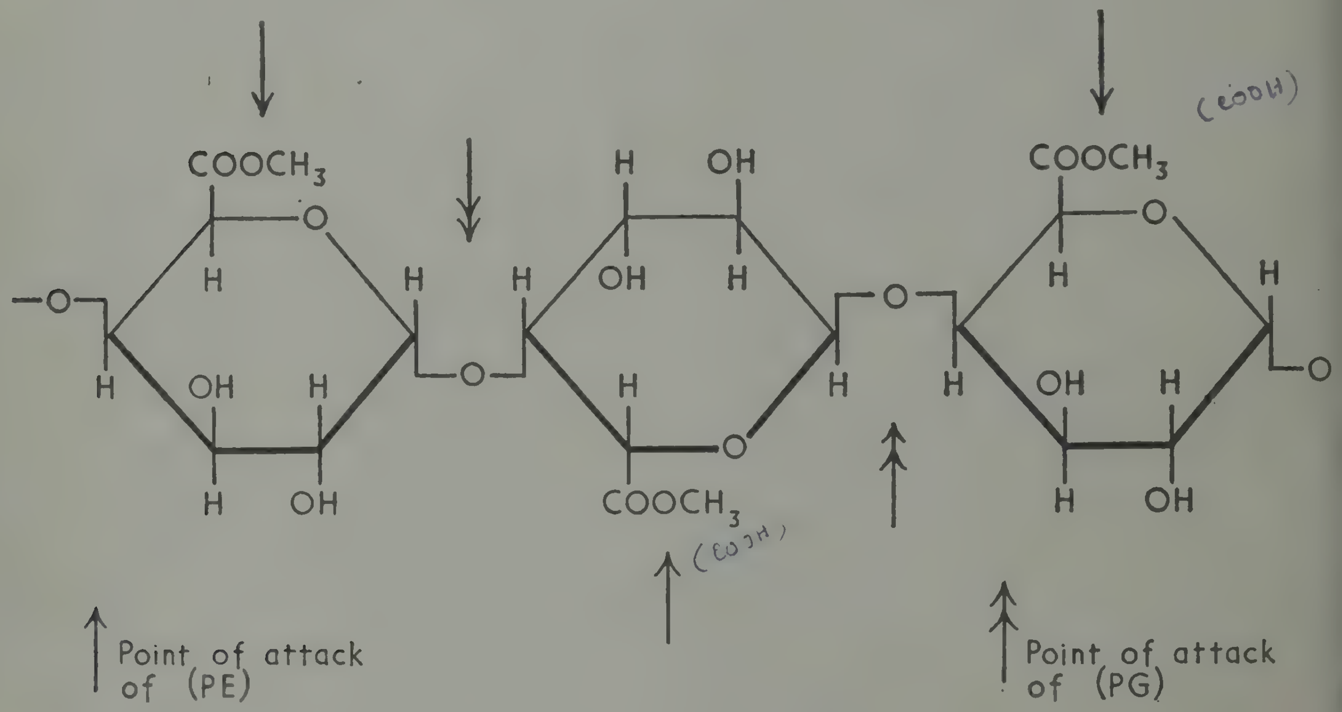
Recent research indicates that pectin is a long chain polygalacturonic acid built up from D-galacturonic acid units united by 1 : 4 glycosidic linkages to form a chain—see diagram page 146.

Naturally occurring pectins have molecular weights ranging from 10,000 to 100,000 and various workers consider that the chains of anhydrogalacturonic units may be cross linked to form the large molecule aggregates (8, 87, 51). In the natural pectins, the greater proportion of the carboxyl groups of the polygalacturonic acid are esterified with methyl alcohol. De-esterification of the pectin by pectin esterase or alkalies produces compounds of decreasing methoxyl content (pectinic acids or low methoxyl pectins), until finally a completely demethylated pectic acid is produced.

The arabinose and galactose often associated with the hydrolysis products of pectin are not now considered to be parts of the molecule. They arise from the hydrolysis of two polysaccharides, an araban and a galactan, which are frequently associated with pectin in certain products.

Various pectic enzymes have been postulated and Kertesz (50) listed six, three of which had experimental verification. An enzyme "protopectinase", which occurs in higher plants and micro-organisms and is responsible for the conversion of the insoluble pectin of plants (protopectin) into soluble pectin, has not been adequately demonstrated to be a separate enzyme, and some workers believe that the solubilization of insoluble protopectin can be carried out by the two better known enzymes. These are, following the terminology of Jansen and MacDonnell (42):

Pectin esterase (*PE*), also known as pectin methoxylase or pectin methyl esterase. This enzyme de-esterifies fully or partially methylated pectins, with the formation of free carboxyl groups and the liberation of methyl alcohol. De-esterification of soluble pectin has but slight effect on the viscosity of the solution, but in the presence of Ca^{++} ions, (PE) action results in the formation of a calcium pectate gel.



Polygalacturonase (*PG*), also known as polygalacturonidase or pectinase or pectolase or pectin polygalacturonase. This enzyme hydrolyses α-1 : 4 glycosidic linkages between two anhydrogalacturonic acid residues in a pectic acid chain, with the liberation of a free reducing group and a simultaneous rapid drop in viscosity.

(The term pectinase is often applied to a mixture of (PE) and (PG).)

Jansen and MacDonnell made the fundamental discovery that (PG) had but slight action on a methylated pectin. Using a (PG) preparation, freed from (PE) by acid treatment and pectinic acids of varying methoxyl content, and prepared by de-esterification of the same sample of pectin, they showed that the rates of hydrolysis of these substrates by (PG) increased with decreasing methoxyl content. These workers advanced the hypothesis that (PG) required at least two adjacent free carboxyl groups in order to hydrolyse a glycosidic bond associated with them. With a fully or partially methylated pectin therefore both (PE) and (PG) are necessary for hydrolysis. In the special case of completely demethylated pectic acid, only (PG) is necessary.

(b) Occurrence and properties of the pectic enzymes

In general, (PE) and (PG) occur together in micro-organisms, but in fruit (PE) usually occurs alone. In the case of tomatoes, however, MacDonnell *et al.* (62), and Hills and Mottern

(32) reported the presence of (PG); Kertesz confirmed that small amounts occurred in ripe, but not green, tomatoes, and recently (58) in a note on a pectolytic factor in tomatoes indicated that its mode of action is different from the (PG) of micro-fungi; part of this pectolytic factor is very stable to heat, and at present its "enzymatic" character is in doubt. (See also under Section (**g**.)

It was first shown by Lineweaver and Ballou (60) that the activity of the (PE)'s of higher plants is markedly stimulated by mono and divalent cations. This effect has been studied on (PE) from various plants, together with various methods of isolation and purification—alfalfa (60), orange (62), and tomato (68, 33, 91). The effect of cations on enzyme activity is more pronounced at lower pH values, while at or near the optimum pH the cations produce very little effect. The pH optima for (PE) preparations are 7·0 to 8·5 for tomato (91, 100), 6·0 for alfalfa (in 0·15M NaCl) (60), 7·5 for orange (in 0·15M NaCl) (62), 8·0 for tobacco (36). For gooseberries and red and blackcurrants 4·3 has been quoted (21), but as the (PE) activity was determined using gel formation in the presence of calcium, the reported pH may be the optimum for gel formation rather than the optimum for (PE) activity.

The (PE)'s from mould preparations have a much lower pH optima; 4·3 to 4·6 for Pectinol A (24) (see also under Section f) and two fractions from Pectinol had optima of 5·0 and 5·5 (68). Preparations from *P. chrysogenum* (88, 3) have an optimum of pH 3·6. Tomato and tobacco (PE)'s have little and no activity respectively below pH 5·0. The (PE)'s from higher plants show definite similarity in their pH activity relationships (68), but the (PE) from Pectinol has a pH activity curve different from those of higher plants. The fungal and the tomato (PE)'s also differ in their resistance to chemical and thermal inactivation, etc. (68, 70). No data are available on the possible differences between the (PE)'s of different preparations from fungi, although some evidence exists that the mode of action of (PE)'s of fungi from different genera may vary (3). The (PE) of Pectinol was slightly activated by salts at the optimum pH (68).

For (PG) preparations from fungi, optimum pH values of 3·7 for *P. chrysogenum* (88) and pH 4·5 for *Botrytis* (95) have been quoted. The pH optimum of a pectinase preparation (PE+PG) prepared by Kertesz from *P. glaucum* Link was 3·0 to 3·5 (50). (PE) preparations from the higher plants are rapidly inactivated on heating. Tobacco (PE) in 5 minutes at 70° C. loses 30 per cent. of its activity, and is completely inactivated after 5 minutes at 80° C. (35). The (PE+PG) preparation of Kertesz (50) mentioned above had an optimum temperature of 40° C. and was completely inactivated after 30 minutes at 55° C. Pectinol is completely inactivated in 10 minutes at 160° F. (70° C.). Partial separation of (PE) and (PG) in fungal preparations has been achieved by at least two methods: Rothschild (99) suggested they might be separated by reason of their different inactivation rates in the presence of acid or alkali, and Jansen and MacDonnell (42) prepared (PG) free from (PE) by alternate treatments at pH 0·6 for 20 minutes at 25° C. and concentration by ammonium sulphate precipitation. Marked inactivation of (PG) took place and the investigators (42) considered the possibility that two (PG)'s might exist, the one acid-resistant and the other acid-labile. McColloch and Kertesz (67) removed (PE) by absorption on ion-exchange resins. At certain pH values the (PE) appeared to be below its iso-electric point and still in the anionic state, and was therefore absorbed, whereas at these pH values (PG) was above its iso-electric point, and still in the anionic state, and was not, therefore, absorbed. These workers were not able to recover the (PE) from the column, and (PE) from fungal preparations has not yet been prepared free from (PG).

(c) The estimation of pectic enzyme activity

Numerous methods of estimation of pectic enzymes have been used by various workers, either for the estimation of (PE) and (PG) separately or the combined action of the two. For kinetic studies and assay of isolated (PE) and (PG) fractions it is essential that the individual enzyme activities be determined separately. In either determination the enzyme preparation is allowed to act on a standard substrate under standard conditions of pH, salt concentration, temperature, etc. In the case of (PE) activity either the liberated methyl alcohol, resulting from the de-esterification of the pectin substrate, is estimated by distillation and oxidation by dichromate (3) or colorimetric determination (36), or the liberated carboxyl groups are estimated by continuous titration (53); usually, an electrometric method is used (62), and a pectin containing 8-11 per cent. methoxyl as substrate. (PG) activity can be determined by following the increase in reducing power of the solution, following the scission of the α-1 : 4 glucosidic linkages; for this purpose a hypo-iodite oxidation method is suitable (50). As mentioned earlier, Jansen and MacDonnell showed that the methoxyl content of the pectin substrate had a profound effect on the velocity of hydrolysis by (PG). (The initial hydrolysis rate for pectic acid was seventeen times faster than that for pectin.) For this reason only a polygalacturonic acid (e.g. an alkaline demethylated pectin) is suitable as a substrate.

The enzyme activities determined by these methods are then expressed as milliequivalents of methyl alcohol, or carboxyl groups, or reducing groups liberated per minute during the initial, linear stages of enzyme action. The formation of a gel from pectin in the presence of Ca ions has been utilized for the examination of (PE) activity. This method is crude and for the examination of pH optima of (PE) preparations gives the optimum pH for gel formation rather than the optimum for (PE) activity.

The separate determinations of (PE) and (PG) are of extreme value for research purposes, but on the technological side they have their disadvantages. Pectin esterase estimation by the titration of liberated carboxyl groups is useless in heavily buffered fruit juices, pulps, etc., and the hypo-iodite method has to determine relatively small amounts of reducing material formed by the hydrolysis of pectin in the presence of large amounts of reducing material initially present in fruit products. In the use of enzyme preparations for the clarification of fruit juices and the processing of soft fruits, the principal technological aim is to obtain a material of low viscosity which will press and filter easily. With both starch and pectin, a profound change in colloidal structure can result from the scission of quite a small number of glycosidic linkages. In the case of pectin, Jansen and MacDonnell showed that hydrolysis of 2 per cent. of the glycosidic links in a number of pectinous substrates caused a 50 per cent. drop in viscosity.

Kertesz (51) also found a rapid viscosity drop in the initial stages of hydrolysis, but concluded that the viscosity decreased more rapidly than corresponded to the increase in reducing groups, whereas Mehlitz and Maas (80) using the calcium pectate method studied the clarification of fruit juices and concluded that the viscosity drop paralleled the pectin degradation. Phaff and Joslyn (48) suggested that the results can best be explained by variations in the pectin substrate used by various workers. If secondary aggregates not connected by primary valencies exist (51), the decrease in viscosity may be faster than the increase in reducing value.

Phaff (89) found that when following the amount of pectin decomposition by the calcium pectate method the precipitate ceased to be formed long before the maximum increase in reducing power had been reached. In studies on the use of pectic enzymes in the fruit juice industry, viscometric methods have been very popular as they have the advantage of speed and simplicity for routine control work. Kertesz (51) concluded that viscometric methods were not suitable for measuring the enzymatic decomposition of pectin, and from many aspects this view is justified. Weitnauer (110) used a viscometric method to study the kinetics of pectin decomposition, but as pointed out by Weber and Deuel (17) (and from the data given above) viscometric methods are not suitable for kinetic studies. Viscometric methods are useful industrially, however, if used with caution and in conjunction with other tests. Weber and Deuel (109) proposed a viscometric method for the assay of commercial " mould " pectinase preparations. The enzyme preparations were allowed to act on pectin solutions under standard conditions and the amount of pectin destroyed (Abbauzahl) was calculated as:

$$\begin{array}{c}\text{Percentage destroyed}\\ \text{(Abbauzahl)}\end{array} = \frac{\text{Va}-\text{V}}{\text{Va}-\text{Vo}} \times 100$$

Va = viscosity in seconds of pectin-containing solution when no enzyme is added.
V = viscosity in seconds of the sample with enzyme after a definite time.
Vo = viscosity in seconds of a sample in which all the pectin has been destroyed.

The use of this percentage figure enabled results obtained on different days to be compared with each other, as it corrected for slight daily variations in the viscosity of the substrate.

In the writer's laboratory a viscometric method for the assay of enzyme preparations has been developed (2) in which the unknown preparations are always assayed against a standard enzyme preparation using a viscometric method. It has been shown that the relationship between percentage pectin destroyed (Abbauzahl) and the logarithm of the amount of enzyme is linear.

The statistical approach used for antibiotic assays (59) based on this relationship is then utilized. Two levels of the standard and levels of the unknown are used (with the ratio High Dose/Low Dose = 4 : 1) on a standard substrate. The potency of the unknown is then expressed as a percentage of the standard preparation. This method has given good results in the comparison of different enzyme preparations, and has been useful as a routine method for various purposes. The same method has been applied to the assay of the α amylase and protease activities of mould preparations using starch and gelatin solutions as the respective substrates (3). Although in general the slopes of the log dose/response curves for standard and unknown are the same, there are indications that with preparations from some fungi the log dose/response curves for the standard and the unknown preparations are not quite parallel, which introduces an error (3). The important observation by Jansen and MacDonnell that a deficiency in (PE) can limit the action of a pectinase preparation will be referred to in more detail (p. 154) in connection with the practical aspects, but it is clearly necessary to know whether a mould preparation is deficient in (PE), and the normal viscometric method described above does not give any information on this point.

Comparisons of various enzyme preparations using two separate substrates, a high and a low methoxyl pectin, do, however, give some information on this aspect (3). For example, a commercial enzyme preparation (A) was compared with a laboratory prepared sample (B). The addition of pectin-esterase from fruits or tobacco to these preparations (under suitable conditions of pH) greatly enhanced the activity of (A) but not (B), indicating that the former was deficient in (PE). Comparative assays using two substrates gave:

High methoxyl pectin as substrate A = 3·33 × B.
Low methoxyl pectin as substrate A = 8·00 × B.

This evidence tended to confirm that (A) was deficient in (PE). Work in progress with pectin and pectic acid as substrates in the viscometric assay suggests a better method of determining whether an enzyme preparation is deficient in (PE). The viscometric method has advantages from the aspect of routine control of fruit processing, but considerably more work is required on this topic, including a comparison of results obtained by the viscometric method using two substrates (pectin and pectic acid) and direct determinations of (PE) and (PG) by the methods enumerated earlier. Even when a fruit product has been enzyme treated to the stage where the viscosity is suitable for pressing and filtration, there is always the possibility that precipitation will occur after pasteurization and standing. Precipitation of samples of such juices with alcohol can give useful information. 70 per cent. alcohol precipitates pectin and the larger degradation products, whereas D-galacturonic acid and other small units are soluble.

(d) The pectic enzymes of micro-fungi (" moulds ")

The formation of the pectinase complex is a common property of many micro-fungi. Bacteria also produce pectin-degrading enzymes, but as far as is known these have not been used commercially in fruit processing. Generally the optimum pH for bacterial pectinase is 6·0 to 8·0, whereas fruit products are in the range pH 3·0 to 3·5, where the bacterial pectic enzymes have little or no activity. The pectic enzymes of bacteria are, however, commercially important in retting (1, 94, 102). Ehrlich (18, 19) prepared pectic enzymes by growing a strain of *Penicillium* (*P. ehrlichii* isolated from sugar beets) in a medium containing 2 per cent. citrus pectin and malt extract; the mycelium was ground with water and the resulting aqueous extract was precipitated with alcohol to give a dry preparation which converted pectin to D-galacturonic acid. Pectic enzymes have also been prepared from other *Penicillia* (50, 89, 88), *Aspergillus flavus-oryzae* group (95), *A. niger* group (92, 93), *Mucor* (95), *Botrytis* (95, 25, 92), and other *Aspergilli*, and a *Monilia* species (53). Many workers included pectin in the medium to stimulate pectic enzyme formation. Harter and Weimer (27-30) studied various species of *Rhizopus* and showed that the enzyme complex was produced on vegetable extracts or on synthetic media with pectin as carbon source, but not on synthetic media containing glucose as carbon source. Menon (81) also studied the influence of the medium on enzyme production. In a detailed study, Phaff (89) grew a strain of *P. chrysogenum* on synthetic media containing various compounds as the sole source of carbon. Although many compounds allowed growth of the organism, only D-galacturonic acid, L-galactonic acid, mucic acid and pectin and pectic acid stimulated the formation of the pectinase complex. Both (PE) and (PG) appeared to be adaptative enzymes and their production was conditioned by the presence in the medium of one of the compounds mentioned. These results were interpreted by Phaff as supporting Yudkin's (113) " mass action theory " of enzyme formation, where a steady state is presumed to exist between the adaptative enzyme concerned and some precursor. In Yudkin's view, the products of enzyme action, as well as the substrate, stimulate enzyme formation, and Phaff indicated from his data that the products of enzyme action, e.g. D-galacturonic acid, had an apparently greater stimulatory effect than the substrate pectin. More recently Gaumann and Böhne (25) showed that with a strain of *Botrytis cinerea* the (PG) was a constitutive enzyme and the (PE) was an adaptative enzyme. Grown on glucose, the organism produced (PG) alone, whereas on pectin both (PE) and (PG) were produced, and the amount of (PG) produced on the two different substrates was the same.

Russian workers (37, 83, 97, 98) reported that strains of an acidophilic yeast, *Saccharomyces oxycocci*, from cranberries secreted (PE). Some strains also fermented sugar, so by choice of the appropriate strain, pectin and sugar, or pectin alone could be removed. Pectin removal during alcoholic fermentation is a common occurrence, and is particularly noticeable in wine and cider manufacture. During the fermentation of wine, up to 40 per cent. of the pectic substances may be removed. In the fermentation of apple juice to cider, Charley found that the whole of the pectin may be removed if the fermentation is prolonged, whereas the fermentation of the pasteurized juices with different pure yeast strains showed no loss of pectin over a 50-day period. It appeared from his results (12) that the natural enzymes of the juice were partially responsible for the pectin removal, but some other factor was also operative.

(e) The production of commercial pectinase preparations

The use of mould enzymes for the clarification of fruit juices was first undertaken by Takamine in the U.S.A. (52). Various mould enzyme preparations were utilized for the removal of proteins and starch in fruit juices (106). Gusmer (26) obtained a patent for the clarification of fruit juices by mould diastase. Most mould enzyme preparations consist of mixtures of several enzymes, and frequently have proteolytic, amylolytic and pectolytic properties. About the same time, both Mehlitz and Kertesz appreciated that pectinase was the most important enzyme in the clarification of fruit juices and claimed patents and published further details (54, 52, 111, 112, 77, 78, 79) for the production of pectic enzyme preparations from " moulds ". Various commercial preparations (Pectinol, Filtragol, Ido, Pectasine, etc.) appeared on the market from 1930 onwards. Two well-known preparations were the Pectinols developed in the U.S.A. and manufactured by Rohm and Haas in Philadelphia, and at Darmstadt in Germany, and Filtragol developed by Mehlitz and produced by Baeyer at Elberfeld and packaged at Leverkusen. No details of the methods of manufacture were published, nor were the organisms known with certainty, although various organisms had been claimed in the patent specifications (79, 112). Böhne (9, 10) prepared mixtures of pectolytic, proteolytic and amylolytic enzymes for the clarification of fruit juices by cultivating *Aspergilli* on water-insoluble proteins, until the latter were solubilized, when the mixture was worked up to a dry powder which was sometimes used with the addition of 0·5-2·0 per cent. activated carbon to prevent the introduction of an unpleasant odour or taste to the juices. The production of mould enzymes was developed by Takamine in the U.S.A. from 1894 onwards (101), with particular reference to starch splitting enzymes. Certain strains of micro-fungi were grown on bran or other solid media under suitable conditions of sterility, humidity and aeration, either on trays or in rotating drums.

The resulting mass of bran and mould mycelium was extracted with water and dry products obtained by concentration *in vacuo* and precipitation with solvents, or ammonium sulphate, etc. During the late war, amylase was produced in large quantities for the saccharification of grain in the U.S.A. and details of different types of plant and the factors such as humidity, temperature control, spore inoculum, etc., and their influence on enzyme production have been published (14, 105). It was usually assumed that similar methods were used for the production of pectinase preparations, which has been borne out by the methods used for " mould " pectinase production in Germany which were investigated by Allied observers (7). Various other " mould " enzyme preparations were also produced by similar methods (23). These reports should be consulted for fuller details, but a brief outline may be given.

In the production of Filtragol :

(a) Bran (1,000 kg.) and water (800 litres) were mixed and sterilized in a rotary sterilizer and allowed to cool.

(b) The bran was inoculated with 100 litres of a spore suspension of *Aspergillus aureus* (Nakazawa). (50 × 2-litre cultures in 5 per cent. molasses.)

(c) The inoculated bran was spread on the galvanized iron trays (2 × 3 metres) of a standard Schilde drier and incubated for 2 days at 35° C. with suitable control of humidity and aeration.

(d) The bran substrate was then dried in a current of warm dry air, well mixed, extracted with alcohol (to remove undesirable smells and flavour) and the mass was then dried, milled and sold as Filtragol.

The method of production of Pectinol was similar. In this case, however, a strain of *Aspergillus wentii* was allowed to grow for 3 days at 32°-37° C. At the end of this period, the mass was extracted with water and the extract containing the enzyme was absorbed on finely ground husks of coffee berries and dried in a current of air at a temperature not greater than 30° C. The action of the Filtragol was examined against apple juice, or by " *its effect on lowering the viscosity of a gelatin solution* " (author's italics).

It is of interest that different organisms were used by the two undertakings. *A. aureus* Nakazawa, known only in the form of the original isolate, is a black *Aspergillus* characterized by a marked orange pigmented reverse to the colonies, and possessing an intense actinomycete-like smell. It has been reclassified by Thom and Raper (103) as a new species *A. foetidus*. The strain received from Germany was similar to an authentic strain of *A. foetidus* (kindly supplied by Dr. K. Raper), and both gave good pectinase production on various media, but pigment production by the German strain was poor. Several other strains of the *A. niger* series examined also produced pectinase to a varying degree ; two of them which showed a marked yellow pigmentation produced as much pectinase as the German *A. aureus* strain (3).

In the choosing of fungi for their biochemical characteristics, the species is not always a reliable guide. Strains within a species exhibit marked variations in their biochemical activities and these may vary depending upon the environment. In the examination of strains of fungi for pectinase production, the medium, temperature and humidity and degree of aeration have to be carefully considered.

Adequate sterilization of the substrate and of the air stream used for aeration are of paramount importance. It is desirable to produce a finished enzyme preparation, balanced in its content of (PE) and (PG). The relative amounts of these two enzymes vary with the medium (depending upon whether the (PE) and (PG) are constitutive or adaptative enzymes for the strain in question) and cultural conditions, and also vary from strain to strain (90, 3). This necessitates suitable selection of strains for commercial production. Crude extracts from cultures can be purified by the usual methods of solvent or salt precipitation. Solvent treatment often results in large losses of enzyme activity unless low temperatures are used, and the (PE) seems more labile to these reagents than (PG) (3). Commercial enzyme preparations are supplied either as the crude dried bran culture, or extracts of the culture dried on bran or kieselguhr, and more potent preparations prepared by concentration and drying of the original extract and then dilution with glucose, lactose or kieselguhr to a standard strength. Preparations containing large amounts of sugar can be rendered sugar-free for laboratory use by washing with 80 per cent. alcohol (24).

The lability of (PE) to solvents may explain why certain commercial enzyme preparations are deficient in (PE), if solvents are utilized in preparing the enzyme concentrates.

The importance of pure cultures and proper sterilization cannot be over-emphasized; the rapid over-growth of contaminating organisms (e.g. *Paecilomyces sp.*, *Mucor sp.*) can completely destroy any enzyme formed by the original inoculum.

(f) The application of pectic enzymes to the preparation of fruit products

Kertesz *et al.* (52, 54, 111) and Mehlitz *et al.* (80, 72, 73, 74, 75) showed that the enzymatic clarification of fruit juices could be explained entirely by the hydrolysis of the pectin content. Mehlitz found, for example, that as the result of enzyme treatment a pear juice could be Seitz filtered to remove micro-organisms, whereas before treatment it could not be filtered. With apples, the addition of an enzyme preparation to the turbid juice from the presses results in a steady drop in viscosity and after a suitable period of time a precipitate separates out, leaving a clear supernatant liquid which can be filtered. If the juice from the presses is filtered bright and enzyme treated, a flocculent material is deposited, and the same type of material is precipitated by the action of pectic enzymes on pectin solutions. These precipitates have been examined by several workers (50, 107) and contain carbohydrate material and a residue which appears to resemble the lignic acid of Ehrlich and Schubert (20). The suspended material in freshly milled apple juice was analysed by Carpenter and Walsh (11) and shown to contain 20-35 per cent. of pectic materials, 1-1·6 per cent. tannin and 20-30 per cent. protein. The pectic enzyme added appears to degrade the soluble pectic materials which act as protective colloids for the lignic-acid-like material. Consequently the latter fraction, together with part of the original soluble pectic material, now rendered insoluble by degradation and disturbance of the colloid equilibrium, plus the suspended matter detailed by Carpenter and Walsh, are all precipitated as a flocculent mass which can be filtered off to obtain a bright juice. Undoubtedly the actual changes taking place are more complicated than this; part of the original suspended material is solubilized by enzyme action, as enzyme treatment of the turbid juice from the mills yields a filtrate with a higher gravity than a sample in which the suspended material is first removed by filtration before enzyme action (3).

If the enzyme treated juice is allowed to stand (e.g. in cold storage under CO_2 pressure) or is filled aseptically into bottles without heat treatment, the enzyme action will continue and further pectic material is likely to be precipitated yielding an unsightly turbid product (13, 64, 104). Marshall showed that the enzyme could be inactivated by heating the juice to 170° F. for 30 minutes. Even when a juice is heat treated after enzyme clarification, a sediment is likely to form on prolonged storage. It was shown that the formation of such a sediment could be prevented by the addition of 0·1 to 1·0 per cent. apple pectin to the enzyme-clarified juice just prior to the final pasteurization (82, 84), and Marshall extended these observations to find the minimum amount of pectin needed to prevent reclouding (65, 66). By taking into account these various factors, it is possible to produce an apple juice, brilliant in appearance and free from sedimentation on storage. Heat treatment, however, definitely imparts a "cooked" flavour, which is in contrast to the clean fresh flavour associated with the product sterilized by filtration only. In the case of the latter product, however, the added pectic enzymes continue their action, and precipitates of pectic materials may be deposited on storage. If the enzyme action is allowed to continue in the cold for some time, the pectin material is degraded to small molecular complexes which are either soluble or are precipitated, after which the final filtered material is usually stable. It has been claimed by several workers (104, 13) that although the cold-filtered, enzyme-treated juice is superior in "bouquet", the finished product is thin and lacks "body". Considerable amounts of pectin are removed when clarification by pectic enzymes is employed, and the loss of this material, together with other soluble material precipitated at the same time by reason of the disturbed colloidal equilibrium, no doubt accounts for this loss of body. In the field of wine and cider manufacture, French workers have emphasized the importance of pectic substances in contributing richness and body (moelleux and velouté) to these products. Warcollier (108) considers that all high class ciders contain pectic substances to the extent of 0·3 to 0·5 per cent. and "pectic materials are essential constituents of a good juice in that they play important roles in the defecation and spontaneous clarification of the juices and should be present in all normally constituted ciders". In wine making, preliminary heating of the marc increases the amount of soluble pectic material in the wine, and it has been shown that the mellowness of wine may be increased by the addition of 0·04 per cent. of pectin. Recent work on this aspect of fruit juice clarification is not available, but as the addition of pectin has been variously claimed both to increase the stability and also the flavour of wines and fruit juices, the problem is worthy of further research. The addition of pectin for either or both of these aims necessitates the inactivation of the previously added pectic enzymes. Removal of these by pasteurization will certainly damage the delicate bouquet of apple juice and other products, and alternative methods of inactivating the enzyme are desirable. It would be of interest to know how far the degradation of pectin in a juice is desirable from the aspect of stability and body. With many varieties of apple juice the precipitate resulting from enzymatic clarification removes materials giving a "flat" or "muddy" taste. The degree of enzyme action determines to a certain extent the character of the final apple juice. Storage of the enzyme treated juice in the cold under CO_2 pressure allows enzyme action to proceed, and results in a juice, light in body, with a clean, thin flavour, whereas pasteurization immediately after a short enzyme treatment produces a juice with a much fuller body. With the latter product, the possibility of precipitation on storage is much greater.

In the production of fruit juices from soft fruits, attempts to press the milled fruit directly are difficult owing to the viscous nature of the product, and some preliminary treatment is necessary. Charley allowed the milled berries to ferment spontaneously until 0·8 to 1·2 per cent. ethyl alcohol had been formed. During this fermentation pectin and other viscous materials were precipitated; the method has the disadvantage that considerable sugar is removed from the juice, and in hot weather particularly the fermentation is likely to get out of hand and lead to the unintentional production of a fine fruit wine. The addition of a pectic enzyme preparation to the milled berries produces under favourable conditions a marked reduction in viscosity, and pressing and filtration are expedited (12, 77, 78).

The amount of enzyme to be used in fruit processing needs to be carefully chosen. The makers of some of the commercial preparations often give useful advice on the amounts of enzyme to be added and supply standardized preparations for specific uses. The Pectinols, for example, are supplied in different grades, A (apple juice), W (grape juice and wine), M (other fruits). The amount to be added depends on the pH, the amount of suspended material and the temperature and duration of enzyme action. The time necessary may range from 3 days at 34° F. to a matter of a few hours at 130° F. The temperature may not—depending on the plant lay-out—be a controllable variable, but elevated temperature, although increasing the velocity of enzyme action, also rapidly stimulates fermentation, frequently with disastrous results.

It is best to adjust conditions to suit the material being processed. Proper manipulation of time and enzyme concentration is sound practice (for example, the viscosity of apple juice tends to increase as the season proceeds, and higher enzyme concentrations are then needed) and, where possible, close laboratory control is most desirable. At the Michigan State Experimental Station, for example, apples were ground and the juice expressed during the afternoon. The enzyme was added during the late afternoon, then placed in cold storage and filtered 16 hours after pressing. Pectinol was added at the rate of 25 oz. per 100 gallons of juice. The workers at the station gave the following table for the amounts of enzyme to be used with different temperatures (22).

OUNCES PECTINOL PER 100 GALLS. OF JUICE

Temperature °C.	5 hours	15 hours	30 hours	48 hours
40°	—	30	15	10
60°	54	18	9	6
100°	14	5	—	—

During the late war, Rohm and Haas of Philadelphia supplied Pectinol 10M. This enzyme preparation has approximately ten times the activity of Pectinol M, and must consequently be used in smaller quantities. In the writer's laboratory enzyme preparations are standardized in terms of an arbitrary unit, M, which is approximately one-tenth the strength of Pectinol 10M. All enzyme materials used are assayed by the viscometric method in terms of this standard, and the amount of enzyme to be added is calculated as a percentage w/v of M.

In the particular case of soft fruits, the viscosity may not be due entirely to pectin, as hemicelluloses, e.g. galactan and araban, etc.—may also contribute to the viscosity, and the rate of breakdown of these materials will vary with the amount of the appropriate hemicellulases in the enzyme preparation used. Examination of the rate of enzymatic breakdown of various batches of blackcurrant pulp using a standardized enzyme and the viscometric method referred to earlier (3) showed that in the majority of batches the course of enzyme action was similar, and the pulps were in a suitable condition for pressing within the usually allowed time limit. In some cases, however, particularly with material which had been canned for winter processing, batches were encountered which were extremely resistant to enzyme attack, and a greatly increased enzyme addition was necessary to obtain a product suitable for pressing within a reasonable time; the exact cause has not yet been determined. With soft fruits, even if the enzyme activity has proceeded far enough to produce a pulp which can be pressed and filtered with ease, the filtered juice, although having a suitably lowered viscosity, may after pasteurization deposit a cloud or even a heavy gel of pectic material. In such cases, allowing the enzyme action to continue in the cold with judicious laboratory control tests of the material by alcohol precipitation, etc., can produce a satisfactory result. It is frequently desirable to standardize fresh enzyme preparations against a standard preparation of known efficiency using juices from the appropriate fruits as substrates.

Apples and other fruits contain (PE) and this ultimately de-esterifies the pectin present. In general the (PE) action alone is not in itself sufficient for the clarification of fruit juices. Plant (PE)'s were used by Russian workers (37, 83, 97, 98) for clarification of fruit juices, but were very slow, taking several days; recently tomato pectase was used with some success (91). [Note: This preparation would almost certainly contain (DP)—see Section (**g**)—and would tend to be more active than (PE) alone.] Pear juice is often rich in (PE) and is frequently added to apple juices which are difficult to clear.

Some industrial pectinases are deficient in (PE) and if they are used for the clarification of fresh juices the (PE) of the juices markedly increases their activity. The deficiency of (PE) in industrial preparations has been considered by Jansen *et al.* (43); they pointed out that the optimum pH range of plant (PE)'s is usually much higher than the pH of the fruit juices, and that it was necessary to add magnesium as a cation activator; under these conditions orange (PE) stimulated the action of the enzyme preparation employed. The addition of cation activators to fruit juices is not desirable, but with soft fruits the (PE) present has a very marked stimulatory effect on the velocity of the viscosity drop, which has a distinct practical advantage and must be taken into account when assaying these enzyme preparations. For this reason the use of the appropriate fresh fruit juice as a substrate is desirable when assaying enzyme preparations for use on fresh juices. In a comparison of two enzyme preparations by the standard assay method, the same result was obtained using either a pasteurized blackcurrant juice or a standard pectin solution as a substrate. When a fresh blackcurrant juice was employed or small amounts of fresh blackcurrant juice were added to the standard substrate, the activity of one preparation remained the same, whereas the activity of the other increased eight times, owing to the fact that the (PE) in the substrate compensated for the deficiency of (PE) in this enzyme preparation (3).

Mehlitz and Maas (80) reported that tannins inhibited the action of commercial enzymes as measured by the calcium pectate method. This point may be of importance in the processing of fruits with a particularly high tannin content. Preliminary investigations with the viscometric method showed that tannic acid and tannin had very little effect on the activity of enzyme preparations examined (3).

(g) The role of natural pectin degrading enzymes in the processing of tomato and citrus products

The pectic substances of tomatoes and citrus products are degraded by the naturally occurring enzymes with a consequent deterioration of texture and appearance, unless the enzymes are rapidly inactivated by suitable processing. It is recognized that tomato juice owes its viscosity principally to its high pectin content, and that tomatoes contain potent pectic enzymes which rapidly degrade the pectins of untreated, comminuted tomatoes (57). (PE) has long been recognized in tomatoes, and more recently a (PG)-like enzyme has been observed. McColloch (69) in a recent discussion of the present data shows that the (PG)-like enzyme rapidly degrades pectinic acids, with the ultimate formation of units approaching pentagalacturonic acid in size. The (PG)-like enzyme cannot attack highly esterified pectinic acids; consequently if the (PE) is rapidly inactivated (as in the "hot-break" process), the pectic materials are not demethylated, and the (PG)-like enzyme has no action. In the "cold-break" process the residual (PE) demethylates the pectic materials present and the pectinic acids formed are rapidly broken down by the (PG)-like enzyme, with a loss of the colloidal properties of the tomato product resulting in poor consistency. The (PG) of tomatoes differs markedly in its mode of action from the (PG) of fungal preparations. There is a very rapid loss of tomato pectic substances in the first few minutes of enzyme action, principally because the (PG) of tomatoes completely destroys the colloidal properties of the pectin when only 10-20 per cent. of the theoretical glycosidic bonds are hydrolysed, whereas with the mould (PG) 40-60 per cent. of the theoretical glycosidic bonds must be hydrolysed to produce the same effect. From various other considerations, including the fact that the tomato (PG) action stops after 50 per cent. of the glycosidic bonds are hydrolysed to yield a polygalacturonide containing five anhydrogalacturonic acid residues which may be further degraded to galacturonic acid by mould (PG), McColloch considers that the tomato enzyme may be more correctly designated as a pectic acid depolymerase (DP) than as a (PG). Conditions of collection and processing of tomatoes which may lead to de-esterification of the pectic substances will result in a low grade product, due to subsequent action of the heat-resistant (DP). In processing, it is desirable either to inactivate all the (PE) by heating the whole tomatoes before milling, or to heat the milled tomatoes as rapidly as possible to reduce pectin degradation to a minimum. According to Kertesz (55) the (PE) of tomatoes was inactivated by heating the juice at 80° C. for 45 seconds. The rate of inactivation was increased with low pH values; in 2 minutes the enzymes were inactivated at 70° C. at pH 4·4, 55° C. at pH 2·5, and 50° C. at pH 1·1, whereas at pH 6·0 there was no inactivation at 70° C. The amount of (PE) in tomatoes has been given by Kertesz (56).

In 1914, Cruess observed that fresh orange juice would not filter easily and, on standing, coagulated to a gel which then settled out, leaving a clear supernatant liquid. Cruess postulated the presence of pectic enzymes and showed that the pasteurized juice did not clear, but retained the desirable cloudy appearance. Heating the juice in the bottle to 85° C. prevented it from clearing, even after storage at room temperature for seven months. Joslyn and Marsh examined the settling of canned orange juice (45, 46), and later made a more detailed study of the effect of heat on the clearing of citrus juices (49). They found that orange and grapefruit enzymes were inactivated in 1 minute at 80° C. at pH 4·0, and lemon enzyme after 1 minute at 70° C. at pH 4·0. Loeffler (61) showed that before citrus juices could be screened, de-aerated and heated to pasteurizing temperature, partial enzymatic clarification of the suspended material occurred. This cloud could be increased by heat treatment which extracted additional pectic substances from the water-insoluble protopectin.

(h) Other aspects of pectin degrading enzymes

Pectin-esterase (PE) preparations have been utilized for the production of low methoxyl pectins from citrus peel by the action of the natural (PE) of these fruits, which is free from (PG) and yields high grade products (86). The use of (PE) from tomatoes yielded products of low gel strength and calcium tolerance (34) due no doubt to the action of (DP).

Preparations of fungal amylase are frequently used for the removal of starch in the preparation of pectin from apple pomace, etc. The presence of pectin degrading enzymes in these amylase preparations has a deleterious effect on the jelly grade of the final product (4). An amylase preparation for this purpose was prepared in Germany by the cultivation of a strain of *A. oryzae* on bran in a similar manner to the method referred to in Section (e). Pectinase formation was inhibited by maintaining a high humidity during the growth cycle (23). A recent German patent (85) claimed the addition of aliphatic alpha amino-carboxylic acids to amylase preparations for selectively inactivating any pectic enzymes present. The possible use of fungal enzymes for the "mellowing" of fruit juices and wines was being actively investigated in Germany (44). The investigators were of the opinion that the addition of certain mould enzymes produced desirable changes in fruit juices and wines, and believed that the idea was capable of extension to other food products. The aim was to produce an enzyme preparation which would simultaneously clarify the juice and produce the "mellowing" effect, and it was claimed that some of the mould preparations which were then in the research and development stage showed definite promise in this respect.

In wine making, the addition of pectic enzyme preparations has often been found useful (6, 31). The natural clearing of wines after fermentation is probably due to the naturally occurring pectic enzymes. Wine made from the fresh juice cleared perfectly, whereas wine prepared from heated juice remained cloudy (31). New wine treated with pectic enzymes cleared in two days, whereas the untreated wine was still cloudy after fermentation was complete.

In addition, the pectic enzymes have been suggested for the preparation of fruit jellies (5, 71), and the enzymatic production of D-galacturonic acid (96) as a raw material for ascorbic acid synthesis (38-41).

Isbell suggested that pectinase might be obtained as a by-product of penicillin production (39), and Russian workers claimed that the mycelium of *P. notatum* and *P. crustosum* had high pectolytic, proteolytic and phosphatase activity (93).

ADDENDA

Degradation of pectin by yeasts (see page 150)

The work carried out by Charley on the influence of yeasts on pectin has been re-examined in the laboratory of the writer. As Charley found that the pectin was removed during the fermentation of unpasteurized, but not of pasteurized juices, it was thought that yeasts might produce a (PG)-like enzyme which could not attack the natural pectin, unless this has been previously de-esterified by the natural (PE) of the juice.

Numerous cultures of yeasts, isolated from cider and other fruit products, were grown in media containing inorganic salts, glucose and either high methoxyl or low methoxyl pectins. The latter substrate can be degraded by (PG) quite readily without the addition of (PE). All the yeasts grew well, but there was no degradation of either pectic material. Luh and Phaff (114) examined numerous cultures of yeasts for their ability to cause pectin breakdown. The majority of the cultures had no effect on pectin, with the exception of a few cultures. *Saccharomyces fragilis* elaborated a (PG)-like enzyme which lowered the viscosity of the pectin and destroyed the jelly strength. This (PG)-like enzyme differed in various respects from the (PG) of fungi. Three other organisms, *Saccharomyces thermantitosum*, *Candida pseudotropicalis*, and *Torulopsis* (*Cryptococcus*) *lactosa*, could also clarify pectin solutions, but at a slower rate.

Other yeast cultures from fruit products have since been examined in this laboratory, but none capable of degrading pectin has yet been isolated. It seems likely that the yeasts do not remove pectin during the cider fermentation by the elaboration of a (PG)-like enzyme. More probably in the unpasteurized juices, the pectin is converted to pectic acid by the natural (PE) of the juice, and the pectic acid is precipitated together with the yeast cells. Further work is in progress on this subject, but there also remains the possibility that some of the yeasts contribute by the elaboration of a (PE)-like enzyme. (See, for example, Refs. 37, 98, 83, relating to the use of *Saccharomyces oxycocci*.)

Assay of pectic enzyme preparations (see page 147)

In the treatment of unheated fruit juices with pectic enzymes, e.g. apple and blackcurrant juices, there is generally enough (PE) present in the fruit juices to ensure that the (PG) in the added enzyme works at maximum efficiency. Under these conditions it is better to standardize the enzyme preparations solely on their (PG) content. This can be done using pectic acid as substrate and the usual method of assay against the standard preparation. Pectic acid at pH 3·5 is not an entirely satisfactory substrate, as it tends to give anomalous viscosities due to the state of dispersion of the pectic acid. A more promising substrate is the glycol ester of pectic acid which is not de-esterified by (PE), but is degraded by the action of (PG). (Matus, 116.)

Inactivation of pectinase in fungal amylase preparations

The treatment of fungal amylase preparations with amino-carboxylic acids to inactivate the pectinase (85) has been examined. Cysteine had no effect on the activity of several pectinase preparations examined, and Matus (116) also found that glycine had no inactivating effect on pectic enzymes.

Specificity and purification of polygalacturonase

Lineweaver *et al.* (115) have prepared highly active and purified (PG) by two methods: from Pectinol 45AP by absorption on alginic acid, elution and dialysis; and from Pectinol 46AP by acid treatment, salt and lead acetate precipitation, and dialysis. The purified enzyme was highly specific and hydrolysed pectic acid at least 5,000 times as fast as it attacked numerous other polysaccharides, including several which contained galacturonic acid residues.

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CHAPTER XII

FRUIT JUICE DEVELOPMENTS IN SOME COMMONWEALTH COUNTRIES

Reference has been made in preceding chapters to the developments of certain fruit juice processes in some Commonwealth countries during and since the last war. Whilst a certain number of these lines were of purely temporary significance, it appears that other products have achieved a more permanent basis and that the industry will survive the immediate post-war period.

The purpose of the present résumé is to present briefly the existing types of processing, together with certain data which have been made available from some of the fruit producing centres by the processing firms themselves or by Government organizations. No attempt at inclusiveness has been made and information has been restricted to that sent from official sources.

AUSTRALIA

The position regarding production of various fruit juice products in Australia has been specially set out for this Bulletin by J. W. Kefford and L. J. Lynch of the Canning Research Laboratory, Homebush, N.S.W., in December, 1948.

1. Type and quantity of juice produced during wartime

Before the 1939-45 War, the production of pure fruit juices in Australia, as distinct from the manufacture of cordials and aerated waters, was restricted to apple juice and pineapple juice, about 100,000 gallons of each product being produced annually.

Commercial processing of citrus juices commenced in 1942 when the U.S. Army in Australia placed large local demands. The production programme was organized very largely by officers of the Division of Food Preservation, Council for Scientific and Industrial Research, who had been conducting a research programme in fruit juice canning since 1938. About twenty manufacturers of cordials were encouraged to instal juice canning lines and the production figures achieved for citrus juices and various other juices and juice products are set out in the following tables.

TABLE 25

FRUIT JUICE PRODUCTION, SEASONS 1942-43, 1943-44

	1942-43 gallons	1943-44 gallons
Orange	472,455	948,926
Lemon	174,838	129,373
Grapefruit	101,237	175,609
Pineapple	245,255	260,323
Tomato	928,601	1,695,138
Orange and Grapefruit . .	—	271,251
Apple	—	377,331
Other	235,537	—

TABLE 26

PRODUCTION OF FRUIT JUICE CORDIALS, SEASON 1943-44

	gallons.
Orange	222,692
Lemon	370,547
Grapefruit	13,742
Orange and Grapefruit	402,059
Lime	11,068
Blackcurrant syrup	229,537

In 1944-45, a poor season caused a decline in production amounting to about 25 per cent., and subsequently much greater reductions occurred owing to fewer Service demands.

The apple juice produced during war-time was a cloudy juice, packed in lacquered cans and fortified with synthetic ascorbic acid to a level of 30 mg. per 100 ml.

2. Products now being made on any considerable scale

Present production is small because the tinplate shortage restricts supplies of containers for the export trade and because the local demand for pure fruit juices is slight, for several reasons :

(a) The public taste favours cordials and aerated waters ;

(b) fruit juices are expensive because fresh fruit prices, especially for citrus fruit, have been high ;

(c) quality is unsatisfactory in some juices, notably orange juice (see below).

Rough estimates of production for the present year, 1949, are set out below :

Apple juice	150,000	gallons
Pineapple juice	300,000	,,
Orange juice	20,000	,,
Grapefruit juice	20,000	,,
Tomato juice	100,000	,,

There is a developing interest in fruit juice concentrates and in the 1948 season 20,000 gallons of apple juice concentrate was shipped to Great Britain in casks.

3. Technical or research development since 1938

The early work of the Division of Food Preservation on fruit juice processing consisted largely in the adaptation of overseas techniques to local conditions and in the testing of Australian varieties of fruits for suitability for juice production. The plants set up during war-time followed orthodox lines, embracing juice extraction equipment, de-aerator, plate-type flash pasteurizer, filler, can closer and cooling equipment.

More recently, since the end of the war, it has been possible to undertake more fundamental research in this field ; for instance, a study of the causes of unsatisfactory quality in canned orange juice, and a critical examination of some of the unit processes in fruit juice canning.

Two distinct problems have been encountered in orange juice canning, both associated with the development of unattractive flavours. The first is the occurrence of a characteristic bitterness in the juice of Washington Navel oranges, which makes about half of Australia's orange crop unsuitable for juice production. The bitter principle in Navel oranges has been isolated in pure crystalline form and is known as limonin. The chemistry of limonin is being studied in the hope that it will lead to a method for the elimination of bitterness.

The second problem in orange juice canning is the rapid development of a " stale " flavour in the canned juice at storage temperatures above about 60° F. The chemistry of this flavour change is obscure, but it has been generally described as an oxidative reaction. However, following the working out of a rapid polarographic method for the determination of oxygen in orange juice (Lewis and McKenzie, *Anal. Chem.*, **19** : 643-646, 1947) it was found that flavour deterioration occurred even in the absence of free oxygen.

This finding led to a reconsideration of existing procedures for canning orange juice, and it was decided that de-aeration could be eliminated. A further modification which had led to an improvement in quality is the substitution of cold filling and " in the can " pasteurization for flash pasteurization and hot filling. Rapid heating and cooling, during " in the can " pasteurization, are achieved by rotating the cans, an operation which can be carried out in simple equipment, for instance, by means of an inclined moving belt on which the cans are spun by friction.

Following the successful marketing in America of several varieties of blended fruit juices, a number of experimental packs of fruit juice blends, based on apple juice, have been prepared. Apple juice with 10 per cent. passion fruit juice is a particularly attractive combination ; apple-lime (2-3 per cent.) and apple-grapefruit (25 per cent.) blends are very refreshing beverages, and apple-pineapple and various apple and berry juice blends merit further attention.

The apple juice produced at the present time is a clear juice, prepared by enzyme clarification, packaged in bottles and available in both still and carbonated forms. The Division of Food Preservation, however, favours a cloudy juice since clarification processes tend to remove much of the fresh apple character from the processed juice.

BRITISH WEST INDIES

The main products from this area are canned citrus juices in concentrated and unconcentrated conditions, citrus pulp and lime juice. The citrus juices have a specific flavour of their own but are regarded highly for the production of squashes. Flash pasteurization has been widely adopted and other American techniques are being rapidly adopted by the processing firms involved.

CANADA

Full details of Canadian production are given in Chapters III and IX.

INDIA

The production of fruit squashes is the only really appreciable phase of fruit juice processing in India to-day. The methods of production have been vastly improved by the producers as a result of a series of important studies by Lal Singh and Girdhari Lal of the Punjab Agricultural College, Lyallpur. Their researches into the quick sedimentation of lime juice and the preparation and preservation of tomato juice have formed the basis for important developments in this industry. On the other hand, no commercial production of vitamin juices or syrups has yet been accomplished.

NEW ZEALAND

The principal fruit juices made in New Zealand are apple, lemon and tomato.

There are no published figures for production, but it is obvious that no spectacular headway has been made there so far. There has been no urge to undertake an extensive advertising campaign, but where local advertising has been adopted, very remarkable sales have been achieved.

The main production of apple juice is in two plants in Auckland, but the annual production is probably no greater than 35,000 gallons. It is probable that this figure will be satisfactorily increased in the very near future by the setting up of a juice plant as an ancillary to apple dehydration in the New Zealand Government Marketing Department's factory at Motueka, in the Nelson district of South Island.

Lemon juice is made almost entirely at the Auckland plant of the Marketing Department. Annual production over the past 8 years has varied between 6,000 and 19,000 gallons, the average figure being 13,000 gallons for that period.

Tomato juice has recently been produced in Auckland, but its production has not yet reached an appreciable figure. The processing of juice closely follows Continental practice. Both the cold and the hot methods of production have been adopted, but since trouble with fermentation occurred with cold processed juice, a change was made to cloudy juice, which appears to have achieved consumer acceptance.

The full, sweet character of the pasteurized juice is preferred by most consumers to the thinner, and perhaps slightly sharper nature of a completely cold processed product.

Most of the New Zealand dessert apples appear to be suitable for juice production, and a proportion of cooking apples can also be used. Few apples make a satisfactory juice on their own, with the main exception of Jonathan and Cox's Orange Pippin.

Sturmer apples provide a juice which is rather too satisfying, but this juice is most valuable for reinforcing weaker juices.

Specific gravities vary between 1·047 and 1·042, but Sturmer juice usually reaches 1·051. Acidities are very diverse: Delicious shows only 0·19 per cent., mild dessert types such as Statesman and Jonathan vary from 0·39 per cent. to 0·45 per cent., whereas Sturmer reaches 0·75 per cent. Tannins range between 0·05 per cent. and 0·07 per cent., but Jonathan is particularly low at 0·03 per cent.

There has recently been an interest taken in passion fruit pulp, and it may be that this material can be developed from New Zealand fruit for export abroad.

PALESTINE

This country has shown very great activity in the last few years in the fruit juice industry. The need for sources of juices as alternatives to those from U.S.A. which could not be purchased on account of the dollar position was apparent to the Palestinian producers and very rapid and far-reaching developments have been and still are taking place.

An official report (Survey of Palestine, prepared by an Anglo-American Committee and revised by a U.N.O. Committee) gave the following information:

" In the seasons prior to 1946-47, an average quantity of about three-quarters of a million cases of fruit per season was taken up by the citrus products industry. In 1946-47, however, with increased quotas for barrelled concentrated juice for beverage manufacture and with commencement of commercial production by eight factories of canned, sterile concentrated orange juice (of which only about 33 tons were produced in 1945-46) and by five factories of canned pasteurized orange juice, it is estimated that the total intake by the products industry in the 1946-47 season was around 1½ million cases of fruit. Production in 1946-47, mainly for export to the United Kingdom, was estimated at :

Barrelled concentrated orange juice	1,630 tons
Barrelled concentrated grapefruit juice	450 tons
Canned sterile concentrated orange juice ..	750 tons
Canned pasteurized orange juice ..	2½ million 20-oz. cans

It is understood that a potential market exists in the United Kingdom for up to at least 3,000 tons of canned, sterile, concentrated orange juice per season in view of requirements for child-feeding schemes."

The present position is that large quantities of straight orange juice, de-aerated and flash pasteurized into small cans, is preferred for sale in England and elsewhere. Concentrated juices (orange, lemon and grapefruit) are barrelled for use in England as bases for soft drinks. Concentrated orange juice with guaranteed high vitamin C potency is despatched to England in A10 cans for the production of orange juice for the Ministry of Food Welfare scheme for children.

Considerable activity is now being shown in oil production. The Pipkin oil press is not used on account of the special nature of the Palestinian fruit, but the Food Machinery Corporation's super-juicer is proving very satisfactory, whilst local firms have been able to design and build equipment of their own specially for this purpose (p. 107). Other developments in very recent years include the production of cattle feed and pectin from citrus wastes, and an attempt to extract vitamin C from the peel.

SOUTHERN RHODESIA

Details of the important production of citrus juices in Southern Rhodesia have been supplied by the British South Africa Company. A brief outline of the project follows:

The only enterprise producing orange and lemon juice concentrates is owned by the British South Africa Company, whose factory is situated on their Mazoe Citrus Estate, some thirty miles from Salisbury, the capital of the Colony.

The factory is equipped with sufficient plant to deal with a present maximum of some 6,500 tons of fresh fruit produced on the Estate during the months of May to October. By far the greater part of this crop is harvested from trees of the Valencia Late variety.

The annual production of the factory exceeds 40,000 gallons of 7 : 1 concentrate (specific gravity 1·350), the greater part of which is exported to Great Britain by arrangement with the British Ministry of Food for distribution to the pharmaceutical and beverage trades in that country.

The method of processing adopted at Mazoe is briefly as follows:

Fresh fruit from the groves is graded before being discharged into a water conveyor which serves the dual purpose of washing and moving the oranges to the oil extraction machines. These are of the rotary table Sicilian type in which the oil is extracted by rupture of the oil vesicles in the outer peel of the fruit, which is otherwise undamaged by the process.

The oil emulsion leaves the extraction machines in a continuous stream and is conveyed by pipes to wire mesh sieves and thence to large Alfa-Laval separators. The separated oil is removed to large tin-lined coppers and after settling for some hours is further clarified by filtration through filter papers and is then canned for distribution to the market.

The scarified oranges in their turn are discharged from the oil extraction machines into another water trough which washes off any adhering oil film left on the fruit while conveying it to the juice extraction room. Here the water is drained off the fruit which then rolls down an inclined table to be sliced by a bank of rapidly revolving stainless steel circular knives.

The halved fruits are conveyed to the hand reamers for juice extraction by aluminium-headed burrs. The extracted juice flows down aluminium troughs to be caught in stainless steel buckets while the discarded peels are carried by water to a sludge pump which transports them to large pits for conversion into compost. (It is hoped in the near future to be able to erect a drying plant to convert this waste into cattle food in lieu of the compost.)

The raw juice is removed to the concentrator room where it is first sieved through rotary screens to remove seeds, rag, etc., and then through fine muslin into 50-gallon tanks. From these the juice is pumped into de-aerators and flash pasteurized. After this operation the warm juice is run into stainless steel tanks from which it is drawn into batch type vacuum evaporators for concentration to the required standard which is determined by the use of suitable refractometers. When the desired concentration has been obtained, the requisite quantity of sulphur dioxide (supplied by a standardized solution of potassium metabisulphite) is run into the concentrator for mixing with the charge which is then removed under vacuum into a large stainless steel barrel filler.

The above is a brief description of the methods adopted in the extraction of oil and the preparation of orange juice concentrate at Mazoe at the present time. Provision is made in the near future for the introduction of automatic reamers, continuous type concentrators and improved de-aerating and pasteurizing equipment, together with the installation of vacuum storage which will further improve a product which has always enjoyed a high reputation both for its flavour and its unusually high ascorbic acid content.

UNION OF SOUTH AFRICA

Production of juices for squash manufacture is still the main concern of the juice industry in Cape Province. A very large plant for the production of unfermented grape juice by the cold process was installed twelve years ago, but is not in regular operation on account of the demand for spirit.

As regards Natal the following details of the production of concentrated orange and grapefruit juices have been provided by Messrs. Tomango Ltd., Merebank, South Coast.

(*a*) *Fruit used*

(i) Orange: Navels, Seedlings and Valencias have been employed. Valencias are preferred, as Navels and Seedlings give a juice which tends to develop a slight bitterness on keeping.

(ii) Grapefruit: Both Marsh Seedless and Triumph varieties have been successfully used. The former yields a juice with a relatively high naringin content, whilst the latter is more aromatic and less bitter but has a high pectin content which produces a viscous concentrate liable to obstruct the free circulation in the calandria-type evaporator. Triumph grapefruit juice concentrate has been observed to gel after casking.

(*b*) *Reaming of the juice*

All fruit going to the reamers is thoroughly washed and rinsed. At this stage, essential oils are removed by passage of the fruit through " Avena " oil recovery machines, and recovered from the oil-water mixture by centrifuging. The fruit is halved mechanically and hand-reamed at stainless steel reaming tables whose burrs operate at 750-1,600 r.p.m. The juice passes through mechanical pulpers of the revolving-brush type having screens with 3 mm., 2 mm., or 1·5 mm. perforations. These large aperture screens are used to give a juice with a high juice-sac content for squash manufacturing purposes. Juice for canning as such passes through a 0·020-in. finisher. Rag and seeds are discarded.

Juice passing to the continuous-operation two-stage calandria-type evaporator is concentrated under a vacuum of 27 inches of mercury, the total time of contact with the heating surfaces being 30 minutes.

Usually a 4 : 1 to 5 : 1 degree of concentration (according to the British Ministry of Food's tables) is desired. On leaving the evaporator, the concentrated juice passes to a cooling circuit where it is injected with gaseous sulphur dioxide, and filled into casks. Sulphur dioxide to the extent of 1,600-1,800 p.p.m. is usually employed. This range gives good protection against the effects of oxidation and browning as well as being satisfactory against microbiological spoilage. In trial shipments during the war years 600-900 p.p.m. SO_2 was found sufficient against the risk of fermentation, but as the juice is not de-aerated and is not flash sterilized either prior to evaporation or subsequently, it is felt that the higher SO_2 values are desirable.

All equipment is either of stainless steel or, where at present this is not available, aluminium is used.

Table 27 provides some data concerning juices produced at the Tomango factory.

TABLE 27

SPECIFIC GRAVITIES AND YIELDS PER TON OF CITRUS JUICES FROM NATAL

Fruit	Year	Specific gravity (20° C.)		Gallons per short ton (2,000 lb.)	
		Range	Average	Range	Average
Eureka Lemons	1945 1946	1·030-1·046 1·034-1·048	1·036 1·039	50-66 50-68	58 61
Washington Navel Oranges	1946	1·054-1·059	1·056	65-69	66
Seedling Oranges	1945 1946	1·038-1·053 1·041-1·054	1·045 1·048	63-90 62-83	76 68
Valencia Oranges	1945 1946	1·041-1·064 1·046-1·057	1·053 1·051	52-80 71-93	63 79
Marsh Seedless Grapefruit	1945 1946	1·032-1·061 1·033-1·052	1·039 1·040	58-84 63-85	71 76
Triumph Grapefruit	1945 1946	1·030-1·051 1·036-1·054	1·045 1·043	50-83 63-88	66 72

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Just before the war Dr. V. L. S. Charley and Dr. T. H. J. Harrison prepared for us a work entitled Fruit Juices and Related Products, which we issued as Technical Communication No. 11 in June 1939.

This bulletin went out of print some years ago and we have ever since been asked to reprint or issue supplements.

Meantime, although the second author has entered other fields of enterprise, Dr. Charley has continued to give ever increasing attention to the scientific and commercial aspects of juice production and he is now acknowledged as a world authority on the subject.

We count ourselves and, in fact, the British Commonwealth, extremely fortunate to have induced him to gather the wisdom of a team of experts and with their aid compile this present survey of recent progress.

For a most apposite foreword we have to thank one whose name is known to agriculturists in every corner of the Commonwealth, The Right Honourable Viscount Bledisloe, P.C., G.C.M.G., K.B.E.

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D. AKENHEAD,
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